UNIVERSITY OF SOUTHAMPTON

PRIVATISATION, LIBERALISATION, AND PROBLEMS OF REGULATORY COMMITMENT AND CAPTURE - ESSAYS IN REGULATION

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ABSTRACT

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This thesis examines an a number of important issues concerning privatisation, liberalisation, and the regulation of firms with market power. After a general introduction in Chapter 1 a model of the optimal level of regulatory commitment is developed in Chapter 2. I examine the relative benefits of commitment and discretion arising from the incompleteness of contracts. Full commitment gives the firm powerful incentives to invest but leaves the regulator unable to bring prices in line with realised costs. Full discretion on the other hand offers no incentives to invest but achieves allocative efficiency. I consider the case of a monopolistic firm with known demand but unknown costs and show that the elasticity of demand, the cost of investment, the regulator's weight on profits and the level of uncertainty are key factors in determining the optimal level of regulatory commitment.

Partial privatisation may be an important means of securing commitment to regulatory policies. In Chapter 3 I consider the partial privatisation of a monopolistic firm to an owner-manager. The government then regulates the firm's price. Both full privatisation and full public ownership lead to productive inefficiency, as all the returns from cost-reducing effort are expropriated by the government. It is optimal for the government to undertake a limited level of privatisation, as this reduces regulatory expropriation and leads to improved productive efficiency.

Even if privatisation programmes and regulatory regimes are carefully designed many inefficiencies may remain. Under such conditions it may be preferable to liberalise an industry. In Chapter 4 I examine the effects of asymmetric information on the regulation of a monopolistic firm when the firm is given the choice of whether or not to liberalise the industry. I thereby determine the conditions under which liberalisation is preferable to the alternative of a regulated monopoly. An alternative application of the liberalisation model is used to examine the effects of regulatory capture on entry decisions. I determine the conditions under which regulated entry is preferable to free-entry.

Chapter 5 provides a summary of my results and suggests future avenues for research.

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Chapter 1

Introduction

This thesis examines a number of important issues concerning privatisation, liberalisation and the regulation of firms with market power. This chapter reviews some of the general literature in this area in order to provide a background and motivation for the research in subsequent chapters. It also discusses the contribution of this research to the literature. It begins with a discussion of the objectives and limitations of regulation in Section 1.1. Even if a regulator is able to credibly commit to its announced policies many inefficiencies may remain. For example, if there is asymmetric cost information the regulator must compromise between allocative efficiency and keeping costly informational rents to a minimum. Section 1.1.1 discusses a number of constraints on the design of regulatory policies and how optimal regulatory policies may be adapted to account for these limitations. If the regulator is unable to commit to its announced policies further problems may arise. Section 1.1.2 examines the consequences of a lack of regulatory commitment, such as problems of underinvestment, possible similarities with commitment problems in other areas of economics, and potential solutions. This provides a background for a model of the optimal level of regulatory commitment in Chapter 2. Section 1.2 focuses on the benefits of privatisation and possible interactions between privatisation decisions and regulatory incentives and policies. This provides motivation for a model of the optimal level of privatisation in Chapter 3, which shows that privatisation may act as a form of commitment to higher regulated prices and foster higher levels of investment. Even if privatisation programmes and regulatory policies are well designed some inefficiencies may remain. Under these condition it may be preferable to liberalise an industry. Section 1.3 discusses the costs and benefits of liberalisation. This provides motivation for the model in Chapter 4, which studies the optimal choice between regulation of a monopolistic firm and liberalisation. An alternative application of that model is used to examine the effect of regulatory capture on entry decisions. Chapter 5 concludes.

The question of how to design regulatory institutions and regulatory policies lies at the heart of government policy towards industry. Since the 1970s most of the state-owned industries in the UK have been transferred to private hands and many of them have been opened up to intense competition. Extensive liberalisation has taken place in the airline, trucking and telecommunications industries in the US, and has spread to many other countries. Many industries such as gas, water, and electricity, however, have natural monopoly characteristics in at least some part of their operations and are therefore unlikely to face strong domestic or international competition in those areas. They have high levels of sunk costs, provide essential services, serve large markets, and have large economies of scale. Under these conditions effective regulatory institutions are required to prevent the abuse of monopoly power, monitor investment and to ensure adequate service provision and quality of supply. The eventual aim may be to liberalise these industries as new technologies become available, but at least in the short-run the design of regulatory regimes remains important.

1.1 The Design of Regulatory Regimes: Objectives, Limitations, and Solutions

Regulatory institutions are designed to overcome problems of market power when there is inadequate competition in an industry, either due to strategic or physical barriers to entry or market dominance by one or more firms. There are a number of objectives that should be considered when designing regulatory agencies and policies.

1. Regulation should ensure that prices closely reflect avoidable costs. In the absence of effective competition or regulation there will be no control over the prices charged by monopolists other than the consumers' willingness to pay. This may result in very high prices and an extremely inefficient allocation of resources.

2. Regulatory policies should be flexible. Many industries face considerable uncertainty, be it in the form of rapidly changing demand and costs conditions, new products or new technologies. Regulation must be adapted to this rapidly changing environment and ensure that prices fall in line with costs as new production techniques are introduced.

3. Regulation should provide strong incentives for investment in new products and new technologies. Unregulated monopolists often have weak incentives to invest in cost-reducing technologies which results in unnecessarily high costs and a loss of productive efficiency. Such dynamic considerations are just as important as achieving low prices.

4. The regulatory regime should provide sufficient stability for investors to be confident of an adequate return on their sunk investments. Firms may be reluctant to invest if there is considerable uncertainty concerning regulatory policies or if they believe that the regulator will expropriate the returns on their investments.

5. Regulators should ensure that firms do not compromise service quality in order serve their customers at low costs. If a regulator enforces low prices there is a danger that firms will reduce their standards in order to maintain high levels of profits.

In a ideal world regulatory policy would perfectly satisfy all of these concerns. In practice, there are many constraints which limit the design of regulatory institutions and policies. Regulators are constrained by the limited availability of information and political pressures. They may be much less informed about demand and costs than the firms they regulate. Regulators are usually not allowed to subsidise the firms they regulate, for instance, because of problems of potential corruption. They will typically be unable to commit to their announced policies in the absence of strong restraints on regulatory power and an effective legal system. In the light of these constraints compromises must be made between the various policy objectives in order for regulatory policy to be feasible. It is these limitations and the constant search to find solutions for them that drives the development of regulatory theory and practice. I shall firstly consider optimal regulatory policies where credible commitments are possible, before considering the problems relating to a lack of regulatory commitment.

1.1.1 Optimal Regulatory Policies with Commitment

The early regulatory literature focuses on static models of regulation of a firm producing a single product. Under perfect information it is optimal to set the regulated price equal to marginal cost. Dupuit (1844) calculates the welfare loss when a firm's price is allowed to deviate from this level. If the price is greater than marginal cost consumers value the good more than it costs to produce. Both parties would benefit if output were increased and the marginal price level were lowered. There are, however, a number of practical limitations on the use of marginal cost pricing.

Firstly, it may entail the monopolist making substantial losses. Many industries, such as telecommunications, gas, and electricity face increasing returns to scale in at least part of their operations. If prices were set equal to marginal cost they would make losses equal to the level of fixed costs. In theory this problem may be solved by paying the firm a subsidy equal to its fixed costs. In practice regulators are usually not allowed to subsidise the firms they regulate. Under these circumstances the optimal regulatory policy must satisfy the firm's break-even constraint. If the firm can only offer a linear tariff average cost pricing is optimal. If nonlinear tariffs are available then it may be preferable to offer customers a price that varies with the quantity of output consumed. A simple form of nonlinear pricing is the two-part tariff. Two-part tariffs are commonly used for gas and electricity pricing, internet pricing and telephone charges. Consumers pay a fixed charge for access to the service plus a price per unit of output. Suppose that a firm's costs are made up of fixed set-up costs plus a constant marginal cost and that consumers are identical. The optimal two-part tariff achieves the first-best outcome. Price is set equal to marginal cost and the fixed charge is set to cover fixed costs. When consumers are heterogeneous the solution becomes more complicated. A high fixed charge may force low demand consumers out of the market. This is inefficient if these consumers are willing to pay a price at least equal to marginal cost. Some allocative efficiency must be sacrificed in order to allow the low demand consumers access to the service. The optimal price is set above marginal cost.

The second difficulty with marginal cost pricing is that it relies on strong informational assumptions. The demand function must be known by both the regulator and the firm (unless there are constant or increasing marginal costs) and both parties must have symmetric information concerning the firm's costs. In practice there are likely to be informational asymmetries constraining regulatory design. The manager of a firm will usually be better informed about its costs and the level of cost-reducing effort than the regulator. She has greater knowledge of the firm's organisational structure, its production methods, and its investment plans. Schmidt (1996) argues that the owner of the firm has "privileged access to its accounting system." The owner can use different accounting methods to manipulate cost information about her firm. The firm may also be better informed than the regulator about the demand for its product. Lewis and Sappington (1988a) claim that firms have superior information about the quality and reliability of their products. In so far as these factors affect demand the firm is better able to forecast the demand for its output than its regulator. Given asymmetric information optimal regulation must trade off allocative efficiency and distributional concerns. Apart from a number of special cases marginal cost pricing will no longer be optimal.

If we assume that the regulator places equal weight on consumer surplus and profits (or there are no costs involved in raising public revenue) and demand can be perfectly observed by both parties optimal regulation remains relatively simple. The regulator delegates the pricing decision to the firm and pays the firm a lump-sum transfer equal to the level of consumer surplus at the chosen price. Loeb and Magat (1979) show that this mechanism maximises social welfare. The profit-maximising firm finds it optimal to set price equal to marginal cost and receives the entire social surplus. This solution, however, does not tell us anything about equity issues. Indeed consumers would be better off with an unconstrained monopoly as they would at least obtain some surplus.[1] If we allow for distributional concerns optimal regulation becomes more complex. Given asymmetric cost information there is a classic adverse selection problem along the lines discussed by Mirrlees (1971) and Spence (1974), amongst others. Baron and Myerson (1982) consider the issue of how to regulate a monopolist with unknown but exogenous costs. Greater weight is placed on consumer surplus than on profits. The regulator sets an incentive scheme to induce the firm to report its costs truthfully. For all but the least efficient type the firm's informational advantage allows it to obtain informational rents. The optimal regulatory policy sets the price equal to the sum of the firm's marginal production and information costs, sacrificing some allocative efficiency in order to reduce the firm's rents. Baron and Besanko (1984a) extend this model to allow for auditing of the firm's costs. The firm's costs are assumed to be a random variable that depends on the firm's private information. Observation of the firm's costs is valuable because it allows the regulator to make an inference about the firm's private information and thereby to reduce its informational rents. The optimal auditing strategy is to audit the firm if its cost report is above some critical value and impose the maximum allowed penalty if costs

[1] Consumers are better off with an unconstrained monopoly provided the monopolist cannot perfectly price discriminate. Under perfect price discrimination the monopolist also receives the entire social surplus.

are lower than anticipated. This deters the firm from overstating its costs.

The conclusions are substantially different if there is asymmetric demand information. Lewis and Sappington (1988a) show that when marginal costs are increasing in output the informational asymmetry is unimportant. The regulator can induce the firm to use its private information in the social interest, thereby obtaining the first-best outcome. However, when marginal costs are decreasing in output the asymmetry does have an impact. The best the regulator can do is to set a fixed price that does not depend on demand. It chooses not to delegate the pricing decision to the firm.

Although the literature has concentrated on how to regulate firms with a single type of private information, in practice it is likely that there are many dimensions of private information. For example, a firm may have privileged information concerning the cost of several of its products, the demand for its goods, and future innovations. Dana (1993) extends the Baron-Myerson model to consider the optimal organisation and regulation of a two-good natural monopoly. The regulator either chooses a centralised organisation in which one firm produces both products or a decentralised organisation in which each good is produced by a separate firm. The marginal cost of each product is private information for the relevant firm and may be either high or low. He finds that unless the marginal costs of the two products are strongly correlated it is optimal to allocate production to a single firm. The optimal regulatory policy sets the regulated price equal to marginal cost whenever costs are low and distorts the price above marginal cost whenever costs are high.

Lewis and Sappington (1988b) and Armstrong (1999) consider the question of how to regulate a firm with both private cost and demand information. They find, in contrast with the previous literature, that it may be optimal to set the regulated price below marginal production costs. Armstrong takes into account the possibility of shut-down by certain types of firm and finds that when private and social incentives conflict sub-marginal cost pricing may still be optimal.

The third weakness of marginal cost pricing is that it does not reveal whether a given project is worthwhile. For example substantial fixed maintenance costs must be paid to keep a power station in operation. If the price of electricity is set equal to marginal cost it is not clear whether social surplus is sufficient to justify incurring the fixed costs. Coase (1945,1946) suggests a possible solution. Consumers should be charged an amount equal to the total cost of supplying them. If they remain willing to pay production is worthwhile. In essence Coase advocates the use of two-part pricing. Consumers should pay a charge that is independent of their consumption level to cover fixed costs.

The fourth limitation of marginal cost pricing is that it provides weak incentives for cost-reducing effort. Under perfect information the regulator can induce the firm to choose the efficient level of effort. It can offer the firm a take-it-or-leave-it contract which pays the firm a fixed transfer if it undertakes the first-best level of effort. However, if the firm's cost-reducing effort is unobservable regulatory policy cannot be directly conditioned on effort. The firm must be given incentives to reduce costs. Marginal cost pricing is then inappropriate. The forward-looking firm would anticipate that it would receive none of the returns from its cost-reducing effort and would therefore choose to undertake no effort. The regulator must instead commit to a policy which gives the firm some return on its effort. Optimal regulatory policy must trade off the objectives of productive efficiency, distributional efficiency and appropriate risk-sharing.

Laffont and Tirole (1986) consider a model which combines elements of adverse selection and moral hazard. There is a continuum of types of risk-neutral firm and the firm's cost is only observed with noise. The firm is informed as to it own true type but the regulator has only a prior distribution over the firm's types. An efficient firm is therefore able to obtain rents by mimicking a less efficient type and choosing a lower level of effort. Optimal regulation involves a trade-off between giving powerful effort incentives and reducing informational rents. An informational rent must be given to all types except the least efficient type and effort is distorted downwards for all but the most efficient firm. There is no distortion at the top. Laffont and Rochet (1998) extend this framework to allow for a risk-averse firm. As compared with the case of a risk-neutral firm informational rents become more costly and therefore the optimal contract moves towards a cost-plus contract to improve the degree of risk-sharing. Downward distortions to effort are greater, but informational rents are reduced. In the discrete, two-type case, the inefficient firm's individual rationality constraint may no longer be binding. An increase in the inefficient type's profits may increase the certainty equivalent by more than the shadow cost of public funds.

Although the regulatory literature typically assumes a risk-neutral principal there are many cases where risk-aversion may be more natural. For example, if the regulated firm forms a large part of the regulator's overall responsibilities. Lewis and Sappington (1995) show that the moral hazard problem can be reduced if a risk-averse principal chooses an appropriate capital structure for the agent. Awarding a private financier a substantial stake in the agent's project both reduces the agent's informational rents and the risk that the principal has to bear.

Informational asymmetries may also give rise to problems of regulatory capture. The traditional literature on regulation assumes that there are benevolent regulators. In practice, however, it is not clear that a regulator will act in the best interest of society rather than the firm she regulates. The "capture" or "interest group" theories of regulation were first developed by Stigler (1971), Posner (1971,1974) , and Peltzman (1976) and have been extended by Laffont and Tirole (1993, ch. 11) and Bliss and Di Tella (1997) amongst others. They suggest that a regulator will use its authority to benefit the most powerful interest groups rather than society as a whole. The regulator in turn will receive monetary bribes or lucrative employment opportunities. Laffont and Tirole argue that without any asymmetries the regulated firm would obtain no rents and would therefore be uninterested in influencing the regulator. Under asymmetric information, however, an efficient firm can obtain rents by mimicking a high cost type and therefore has an incentive to bribe the regulatory agency not to reveal its information. To avoid corruption the government must reduce the efficient type's rent and pay a greater reward to the regulator. This results in a less powerful incentive scheme for the inefficient type and a loss of social welfare.

Splitting regulatory duties and monitoring between several regulatory agencies may reduce the extent of collusive behaviour and enhance welfare. Laffont and Martimort (1999) argue that the separation of powers means that each regulator has less information at it disposal and they are therefore less able to collude with a regulated firm. For example, suppose that there are two regulators. Each observes only one piece of information, allowing the firm to obtain some informational rents. The economic regulator controls the firm's production costs, while an environmental agency controls whether or not the firm pollutes the environment. If the regulators are forced to act non-cooperatively they are able to extract less rents from the firm than if they can cooperate and pool their information. Less distortionary mechanisms may then be used by the government to deter collusion and social welfare is improved. In Laffont and Martimort's terminology the collusion-proofness constraint is relaxed.

The separation of powers is equally important if there are several interest groups. A single agency can help coordinate pressure group influence if they have a common interest. Laffont and Martimort (1998) show that the existence of specialised agencies weakens interest group influence over regulation and improves social welfare.

1.1.2 The Commitment Problem and Underinvestment

The literature reviewed so far implicitly assumes that the regulator can credibly commit not to revise its regulatory policies once new information has been revealed or once effort or large capital investments have been sunk. If such commitments are not forthcoming or feasible there are further difficulties for regulatory policy. For example, consider the Baron-Myerson model discussed earlier. If the regulator cannot commit not to renegotiate its regulatory policy it will set price equal to marginal cost once the firm has made its cost report. The forward-looking firm will anticipate this behaviour and will therefore have an incentive to overstate its marginal cost to obtain informational rents. The regulator must take this incentive into account when designing its regulatory policy. In equilibrium informational rents will increase by more than the gain in consumer surplus from setting the price equal to marginal cost and social welfare will be reduced. The regulator would like to commit to a price above marginal cost, sacrificing some allocative efficiency to limit the firm's informational rents. However, in practice it is unable to do so. There are similar difficulties in the Baron-Besanko model if the regulator cannot credibly commit to its auditing policy. If the firm recognises that the regulator might not audit its costs, auditing loses its deterrent value and again the firm has an incentive to overstate its costs.

In essence a lack of commitment allows opportunistic behaviour by the regulator and can result in significant ex-ante inefficiencies. Firstly, there may be a problem of hold-up. Firms may underinvest in specific assets because they fear expropriation of the returns on their investment. Secondly, there may be a ratchet effect in dynamic regulatory relationships. A low-cost firm will be reluctant to reveal its private information early in a regulatory relationship if the regulator cannot commit not to use this information to tighten future incentive schemes. Low-cost firms may overstate their costs or underinvest in cost-reducing effort to conceal their private information and protect future rents.

Williamson (1975, 1985) provides an extensive discussion of hold-up and the question of relationship-specific investments.[2] Firms often make investments that are specific to particular transactions. For example a component manufacturer may invest in a design that is suitable for just one buyer. This will have little value for other firms. The nature of such investments means that they are more valuable within the relationship than if it comes to an end prematurely.

The incentive for a firm to make investments depends on its expected return. In

[2] See Malcomson (1997) for a detailed analysis of hold-up problems in the labour market. Hart (1995) provides a non-technical guide to the incomplete contracts literature.

the absence of a credible commitment to a fair return or a binding contract, the buyer can bring the relationship to an end and reduce the return on the other firm's investment. That threat can be used to bargain away some of the ex-post returns from the investment, reducing the seller's incentive to invest. Investment will typically be below the efficient level. The extent of underinvestment will depend on whether there are any outside opportunities for the seller. These will generally improve the seller's bargaining position and raise its payoff, increasing its incentives to invest.

In the context of regulation there is a temptation for a regulator to exploit the sunk cost nature of a firm's investment. Once sunk investments have been made by a firm, the regulator has an incentive to tighten price controls or the rate base and expropriate some of the returns from the investment. The forward-looking firm will anticipate this behaviour and therefore limit its exposure by undertaking lower levels of investment. Unless the regulator can credibly commit not to deviate from its announced policy many important investments may not be made.

Gilbert and Newbery (1994) provide evidence of a move towards underinvestment in the US electricity supply industry. "In 1977 electric power utilities had more than 650 projects in the planning stage, of which about one-half were more than 500 MW in size. In 1986, the total number was 64, of which 7 were more than 500 MW in size". This may be explained by a shift in regulatory policy towards disallowing returns on imprudent investments. The use of smaller plants implies a reduction in capital intensity and gives the regulator less opportunity to expropriate sunk costs.

The extent of underinvestment by any given firm will depend on its sunk costs and the degree to which it can retaliate if the regulator reneges on its announced policies. If the firm can reallocate most of its capital the underinvestment effect will be relatively weak. Furthermore, if the firm can impose high costs on the regulator by retaliating, the regulator may be deterred from revising its announced policies. For example firms may reduce investment or abandon future investment plans. Newbery (1994) suggests such actions may be very costly if high levels of investment are required to meet growing demand for essential services.

In hold-up models, such as those discussed above, commitment to announced policies is important because it fosters higher levels of investment and improves productive efficiency. Regulatory commitment, however, plays an equally important role in terms of information revelation. Baron and Besanko (1984b) consider a two-period extension of the Baron-Myerson model. It is assumed that the regulator is able to commit to its regulatory policy for the length of the regulatory relationship. The optimal price in each period is set equal to the sum of the firm's marginal production and information costs. If the firm's marginal costs are the same in each period it is optimal to repeat the static policy. The regulator learns the firm's private information in the first period, but chooses not to use this information as a lower price would increase the firm's informational rents by more than the potential gain in consumer surplus. It is the regulator's ability to commit that allows it to repeat the static contract, sacrificing ex-post efficiency to improve ex-ante efficiency. If such a commitment were not possible the regulator would set the price equal to the firm's marginal production cost in the second period, expropriating the firm's rents. Anticipating this behaviour the firm would have an incentive to overstate its costs in the first period, mimicking less efficient types. This problem of excess pooling behaviour is an example of the ratchet effect, first formalised by Weitzman (1980).

Freixas, Guesnerie and Tirole (1985) show that a regulator will progressively revise a firm's incentive scheme to incorporate new information provided by the firm's performance. Firms will therefore underinvest to avoid more demanding incentive schemes in the future that will jeopardise their informational rents. In equilibrium there may be substantial pooling with efficient firms mimicking inefficient types. Laffont and Tirole (1993, ch. 9) obtain similar results in a more general model which allows for non-linear incentive schemes and a continuum of types of firm.

There is no simple solution to the problem of excess pooling. If the regulator offers the firm a transfer in the first period which offsets its incentive to overstate costs, the firm may then have an incentive to understate its costs in the first period and quit the relationship in the second period. The inefficiency remains. The existence of more than one regulator, however, may weaken the ratchet effect. Olsen and Torsvik (1993) show that multiple principals give rise to weaker incentive schemes and smaller informational rents. This reduces the incentive for inefficient pooling behaviour. Surprisingly, collusion between the regulator and the firm may also mitigate the ratchet effect. Olsen and Torsvik (1998) show that the possibility of corruption makes it in the principal's interest to reduce the firm's informational rents in future periods. The firm then has less funds with which to bribe the regulator and it is less costly for the government to prevent corruption. Lower rents, however, mean that firm has less incentive to pool its type in the first period of the relationship.

Problems relating to a lack of commitment are not unique to the regulatory literature. They are relatively common in industrial economics and the economics literature in general. Malcomson (1997) discusses hold-up in relation to labour markets. He shows that if turnover costs are present there may be hold-up of general as well as specific investments. Inefficiencies may be wide-ranging as firms have insufficient incentives to invest in general as well as specific training and capital.

Kydland and Prescott (1977) discuss the time-consistency problem in macroeconomics. The government's preferences are assumed to be a function of the natural rate of output and inflation, so it is willing to trade off higher inflation for a higher level of output. The nature of the economy is such that only unanticipated inflation causes a rise in output. Private agent's expectations will be correct in any pure strategy equilibrium. Suppose that the government can commit to its monetary policy. Output will be equal to the natural rate regardless of the chosen level of inflation. It is therefore optimal for the government to set inflation equal to zero.

However, this solution is not time consistent in a multi-period game without commitment. If expected inflation is equal to zero and the government is free to choose any level of inflation the government has an incentive to act opportunistically, attempting to raise the level of output with inflationary surprises. Rational private agents take this incentive into account, such that expectations of inflation rise in line with actual inflation and the economy remains at the natural rate. The government is thus strictly worse off if it cannot commit to its monetary policy.

Similar difficulties exist in relation to research and development and patenting. If the government can precommit to its policies it is optimal to issue patents of long duration. Firms will then receive a high return on their investments and have a strong incentive to invest in the development of new products and processes. However, once these innovations have been patented the government has an incentive to renege on it policy and shorten the patents, increasing competition and ex-post efficiency. Firms will take this incentive into account and choose not to invest. Ex-ante efficiency is therefore reduced. The government is again worse off than if it could commit to its patenting policy. Greater progress seems to have been made in overcoming the commitment problem in R & D and patenting than in many other areas of economics. The use of patents is firmly embedded in contract law and governments are unlikely to overturn them.

Incentive problems are common in a wide range of dynamic relationships. Holmström (1999) considers a model of reputation formation in which a manager is responsible for putting forward investment projects for a risk-neutral firm. The manager's ability is unknown and both parties have identical prior beliefs concerning possible types. The performance of the manager's chosen investment may reveal information concerning the manager's ability and thereby affect his future reward. The manager may therefore have an incentive to choose inappropriate investments to avoid revealing his type. In essence a risk-averse manager prefers investments which do not accurately reveal his ability as they reduce the riskiness of his future income. Such investments may, however be characterised by a low probability of success and small expected returns. This result is closely related to the ratchet effect. In this model risk-averse managers, who must choose investments without knowing their types, undertake inefficient pooling behaviour to reduce uncertainty concerning their future incomes. By contrast, in the model of Freixas, Guesnerie, and Tirole discussed earlier, firms with private information pool their types to protect future informational rents.

There are a number of potential solutions to the commitment problem which may improve credibility and reduce inefficiencies. In principle commitment may be achieved through the use of long-term contracts. In practice, however, regulatory relationships tend to be governed by short-term contracts. This arises for two main reasons. Firstly, there are legal limitations on the extent to which current administrations can bind future ones. In the UK price reviews are set every four to five years. Secondly future technologies or demand cannot be perfectly contracted upon. There are many contingencies which cannot be foreseen and investments may be too complex to be verifiable. Moreover there may be similar implications if long-term contracts can be renegotiated. Laffont and Tirole (1993, ch. 10) consider a two period version of their standard model. Suppose that the regulator commits to a long-term contract which sets the optimal static incentive scheme in each period. This contract will be enforced, provided that at least one of the parties wishes it to hold. If the firm produces at a high cost in the first period the regulator may infer that it is an inefficient type. It is then in the interest of both parties to renegotiate the contract to give stronger incentives to the firm. The problem is that this renegotiation raises the rent of the efficient type, if it mimics the inefficient type in the first period. Effort incentives are again distorted downwards.

Grossman and Hart (1986) suggest a relatively simple solution to the hold-up problem. The party that invests should be given all the bargaining power in any negotiations that take place after the investment has been sunk. The investor will then receive the full returns from the investment and will choose to invest efficiently. Malcomsom (1997) argues that this can be achieved in labour markets by a contract that gives the firm the right to set wages after it has sunk its investment and any uncertainty has been resolved, but gives the employee the right to quit freely. Such a solution, however, would be inappropriate in the case of regulatory policy. If the firm were given all of the bargaining power in negotiations, the regulator would be unable to regulate the firm's profits or pass on the benefits of lower costs to consumers.

A third class of mechanisms to improve credibility and efficiency relies on the use of repeated games.[3] The regulator will resist the temptation to make ex-post revisions of policy if the future costs from a loss of credibility exceed the short-run gains. With a short-term relationship agreements between the regulator and the firm will typically collapse with the result that there is little investment. However, with an infinite horizon many superior outcomes for investment can be sustained. Salant and Woroch (1992) show that if each party can credibly threaten to punish the other heavily in the event of a departure from their announced strategies, a near efficient level of investment can be sustained. A similar solution exists for the time-consistency problem in macroeconomics. Barro and Gordon (1983a,b) show that in an infinite horizon game punishment strategies can be used to reduce the degree of inflationary bias.

Reputational effects may also be important for building credibility. Backus and Driffill (1985a,b) consider a model with two types of government. A wet government has an incentive to inflate the economy in a single period game. A hard-nosed government always chooses to set inflation equal to zero. The public is uncertain as to which type of government it faces. They show that in a finitely repeated game a wet government may choose not to inflate. By choosing a low level of inflation it builds a reputation for being hard-nosed which increases the credibility of its anti-inflationary policies and reduces expectations of inflation in the future. A similar approach could be used to overcome the regulatory commitment problem. For example, suppose that there are two types of regulator. A tough regulator has an incentive to set high prices, giving firms a reasonable return on their investments. A weak regulator acts

[3] I shall give a more detailed discussion of these issues in the introduction to Chapter 2.

opportunistically and sets the regulated price equal to marginal cost. In a finitely repeated game a weak regulator may choose to set high prices in order to build a reputation for being tough. There are difficulties, however, with such an approach. If a regulator maintains high prices for a long period prices will increasingly diverge from marginal cost and allocative inefficiencies will be growing. It seems unlikely that a weak regulator will maintain high prices taking such losses into account. Furthermore if the firm's realised costs are very low the benefit of reducing prices may outweigh any reputational effects.

There may be actions that the regulator can take to endogenously generate commitment. Williamson (1983) suggests that hostages may be posted to achieve efficient exchange. For example, the regulator could post a bond, which would be delivered to the firm if the regulator reneged on its announced policies. Such a bond would have to be sufficiently large to offset the regulator's incentive to implement marginal cost pricing once investments have been sunk or the firm's private information has been revealed. The regulator would then be deterred from reneging and the bond would not need to be paid out. Such a bond, however, may itself be subject to problems of expropriation. For example, if the value of specific investments is uncertain a firm may overstate the value of its investment and then expropriate bonds of this value by claiming that the terms of the agreement with the regulator have been broken.

Post retirement employment opportunities with regulated firms may lessen the regulator's incentive to act opportunistically and therefore strengthen credibility. Salant (1995) shows that regulators may be rewarded for lenient regulation by lucrative appointments on the board of directors of regulated firms.

Bilateral trading may be a further means of supporting credible commitments. If both parties invest in relationship specific assets their exposure to the risk of expropriation can be equalised. This reduces the incentive of each party to renege on its announced strategies. In the context of regulated industries such a solution seems impractical unless the government takes an active role in financing sunk investments.

Institutional mechanisms play a key role in fostering credibility. Levy and Spiller (1994,1996) argue that three types of restraints are necessary for regulatory credibility. Firstly, there must be "substantive restraints" on the regulator's discretion. The regulator should not have unlimited freedom to revise her announced policies once investments have been sunk. Secondly, there must be "procedural restraints" on revising the regulatory regime. If the government is able to intervene arbitrarily in regulatory policy or is free to appoint a new regulator, who may implement tighter regulatory policies, credibility will be weak. Finally, there must be an effective legal system to ensure that these restraints are enforced. An example of legal constraints on regulatory opportunism is the requirement in the United States that the firm be allowed an adequate rate of return on "used and useful" capital. This ensures that the firm earns on normal rate of return on any capital that has actually been used. Gilbert and Newbery (1994) show that such restrictions on the regulator's behaviour reduce its incentives to engage in opportunistic behaviour and expropriate the returns from a firm's sunk investments. It is therefore possible to sustain efficient investment under a wider range of conditions than in the absence of such restrictions or under price regulation.

It is clear that, under certain conditions, commitment may be achieved. There are, however, potential costs of commitment or equivalently benefits of discretion. Firstly, discretion allows harmful policies to be reversed. This may be particularly important if some regulators are non-benevolent or face undue political pressure. For example, if a regulator is captured by the firms it regulates it may set inefficiently high prices. A discretionary regime would allow its successor to lower prices and pursue policies that are more favourable to consumers. Secondly, in a rapidly changing environment with new technologies and falling costs a discretionary regime allows the regulator to pass on efficiency gains to consumers. Laffont and Tirole (1992) argue that an important justification for discretion is the difficulty of signing complete state-contingent contracts. For example, a central bank may wish to relax monetary policy if signals suggest the beginning of a recession. Such signals may be difficult to characterise. The central bank may be better off under discretion than if it has to follow rigidly defined rules which force it to pursue inappropriate policies. Similar reasoning applies to regulation.

Clearly, in determining whether or not a regulator should commit to its policy announcements, there is a trade-off between the objectives of flexibility and productive efficiency. Regulatory policies should adapt to new information as uncertainty is resolved. However, such responsiveness brings with it the danger of opportunistic behaviour by the regulator and ex-ante inefficiencies. The contribution of Chapter 2 is to examine the relative benefits of commitment and discretion using a simple static approach and to highlight the factors that are important in determining the optimal level of regulatory commitment. I assume that there is a monopolistic firm facing known demand but unknown costs. The regulator is unable to commit to the price that it will set at the end of the period, but can commit to the price being within a chosen interval. The width of this interval then determines the degree of regulatory commitment. Full commitment provides strong incentives for investment as the firm is a residual claimant on its cost savings. However, it leaves the regulator unable to bring prices in line with realised costs. Full discretion on the other hand offers no incentives for investment but achieves allocative efficiency. The optimal level of regulatory commitment trades off these effects. I find that the elasticity of demand, the cost of investment, the weight on profits, and the level of uncertainty are important in determining the appropriate level of commitment. Relatively little attention has been paid to optimal degree of commitment in the regulatory literature.

There are a number of related papers. Laffont and Tirole (1992) compare social welfare under a commitment solution with welfare under non-commitment. The optimal complete contract trades off efficient investment under long-term contracts with the possible correction of undesirable policies by an honest government under short-term contracts. Their model differs from that of Chapter 2 as the justification for discretion is to overcome problems of regulatory capture. In my model the advantage of discretion is that prices are adapted in line with realised costs. Furthermore they restrict their analysis to the two extremes of commitment and non-commitment.

Baron and Besanko (1987) allow for the alternative of a fair regulatory mechanism. Fairness requires that the firm give up its right to withdraw from the regulatory relationship in exchange for the regulator allowing it to earn non-negative profits given information revealed in earlier periods. In essence fairness is a form of partial commitment as it limits the regulator's opportunism. Social welfare is shown to be highest under commitment, but fairness is superior to no commitment as it enables the regulator to implement fully separating policies. Problems of inefficient pooling behaviour are no longer pervasive as the firm cannot quit the regulatory relationship in the second period.

The degree of regulatory commitment is closely related to the length of the regulatory lag between price reviews. Armstrong, Rees, and Vickers (1995) show in their dynamic model of optimal regulatory lags under price-cap regulation that long regulatory lags may strengthen incentives to invest. Firms are in effect residual claimants on their cost savings until the regulator is able to revise the price-cap. Consumers may nevertheless be worse off under longer lags as prices diverge from realised costs for longer periods

If the regulator has limited precommitment powers it may nevertheless be possible to foster high levels of investment. Sappington (1986) shows that inefficient regulatory bureaucracy may be substituted for commitment to regulatory policies. By making it costly to monitor the firm's realised costs, bureaucracy allows some cost reductions to go undetected. This leaves the firm with positive profits if cost reductions are achieved.

It may also be desirable to limit the regulator's discretion if its preferences differ from those of the government. Armstrong (1995) considers the desirable limits to discretion in an adverse selection model. Suppose the principal delegates regulation to an agent with unknown preferences. The agent has superior information concerning the firm's costs. Limiting the agents's discretion prevents her pursuing undesirable policies when her preferences differ significantly from those of the principal. However, it also limits her ability to use her superior information in a desirable way. The appropriate level of discretion trades off these effects.

There may be an important relationship between privatisation decisions and the future regulation of an industry. The level of privatisation or the number of firms that remain to be privatised may be an important determinant of the credibility of government or regulatory policies. These effects should be taken into account when privatisation schemes are designed.

1.2 Privatisation and Regulatory Incentives

The traditional literature on privatisation discusses four main motives for a transfer of ownership from the public to the private sector.[4] Firstly, privatisation may improve economic efficiency as managers' incentives change from welfare maximisation to profit maximisation and private shareholders have greater incentives to monitor management. Furthermore the threat of takeovers may force managers to improve efficiency.[5] Secondly, privatisation may improve the firm's bargaining power when negotiating with workers or Trade Unions and thereby allow it to lower costs and improve efficiency.[6] Thirdly, the sale of public assets raises revenue for the government

[4] I discuss these issues in more detail in the introduction to Chapter 3. For a detailed discussion of privatisation in general see Vickers and Yarrow (1988).

[5] Private shareholders' incentives to monitor management may nevertheless be relatively weak. If there are a large number of shareholders, individual shareholders may try to free-ride on the efforts of others. As a result relatively little monitoring may actually take place. Grossman and Hart (1980) show that a similar problem affects takeovers. Potential raiders will only collect information concerning a firm's inefficiencies if they can earn substantial profits from the takeover. If a takeover bid is made, individual shareholders may choose to retain their shares to benefit from the increase in the share price caused by the raid. The raider will then be unable to buy the shares for less the post-raid price and the bid will be unsuccessful.

[6] Haskel and Szymanski (1992,1993) consider a bargaining theory of privatisation where costs are modelled explicitly as wages. The prevailing wages are the outcome of a bargaining process between the firm and its workers. Public sector firms have wider social objectives than firms in the private sector and also face a soft budget constraint. Privatisation thus enables firms to lower wages and improve efficiency.

which may be used to lower taxes or reduce the budget deficit. Finally, privatisation may be used as a means of promoting greater public involvement in industry through wider share ownership. Schmidt and Schnitzer (1997) compare a number of different methods of privatisation to determine their relative benefits in terms of raising revenues and promoting efficiency. They conclude that English auctions yield an efficient allocation of property rights under a wide range of conditions, but generally do not maximise privatisation revenues.

Assuming that privatisation is an important means of promoting efficiency and raising revenues one should also consider the effects of privatisation decisions on future government and regulatory policies. To date relatively little attention has been paid to these issues.

Chapter 3 considers the partial privatisation and regulation of a monopolistic firm under imperfect information and examines the determinants of the optimal level of privatisation. The main contribution of the chapter is to illustrate the wider importance of privatisation decisions concerning a single firm or industry. They may have significant effects on future incentives to regulate an industry, managerial incentives for cost-reducing effort and social welfare. I assume that there is a monopolistic firm facing known demand but unknown costs. The firm is initially under public ownership. The government chooses to sell a proportion of the equity in the firm to an owner-manager to raise revenues. It then regulates the firm's prices but does not interfere in its management. The government chooses the level of privatisation strategically to influence its own future incentives for price regulation and thereby to influence the manager's effort decision. Partial privatisation, is in effect, a form of commitment to higher prices and can therefore lead to higher levels of effort and improved social welfare.

There are a number of related papers. Ireland (1995) develops a privatisation and regulation model to examine optimal surplus sharing regulation before and after privatisation. The government sells the firm's shares before the regulator decides the firm's share of gross surplus and the firm makes its investment choice. Investment incentives are improved if the government can credibly commit to regulatory policies before privatisation and implement looser regulatory policies. If such commitment is not possible tighter regulation will be pursued and the firm will undertake significantly less investment. The effects on social welfare, however, are found to be relatively small. This result is due to the regulator's ability to commit to regulatory policy before investment decisions are made. If the regulator is unable to commit to its announced policies, as is the case in Chapter 3, welfare losses may be much more substantial.

Bös (1991) considers an alternative view of partial privatisation. The government retains a share of the firm in order to maintain influence over its decision-making. It chooses to regulate the firm internally by sending government representatives to its board of directors rather than regulating it externally through price regulation. The board is therefore made up of a combination of private shareholders who wish to maximise profits and government representatives who wish to maximise social welfare. The outcome is a compromise between welfare and profit maximisation, which depends on a bargaining process between the two sets of representatives. Higher levels of privatisation raise the bargaining power of the private owners and increase the weight on profits in the firm's objective function. This leads to improved productive efficiency but reduced allocative efficiency, as the profit margin increases. Bös' model differs from that of Chapter 3 in two important respects. Firstly it focuses on the case where the government chooses to intervene directly in the internal decision-making of the firm rather than pursuing traditional regulation. In the UK governments have typically made a commitment not to intervene in the management of the firm after privatisation. Secondly, Bös assumes that under partial privatisation the government gains insider knowledge. I instead assume that the government can only observe realised costs. The benefit of privatisation is that the manager gains a greater stake in the firm's profits.

Most of the related literature on privatisation and regulation, however, has focused on wider privatisation programmes rather than the sale of single firm. Nomer et al (1997) use a reputation model to examine the sale and regulation of a sequence of firms when the monitoring of regulatory compliance is costly. The government is interested in raising revenues in addition to improving efficiency. They find that the government monitors the firm more loosely than in a standard regulation model as this increases privatisation revenues. A gradual programme of privatisation may also increase government revenues. Armstrong and Vickers (1996) suggest that the desire to earn revenues from future privatisation sales may deter government opportunism. It will be reluctant to renege on announced regulatory policies if this jeopardises later sales.

Clearly, even if privatisation and regulatory policies are carefully designed there remain many problems for the regulation of firms with market power. For example, there may be a rapid introduction of new technologies which the regulator has not anticipated or difficulties determining suitable price-caps or surplus-sharing schemes. Important information may not be available. Given these concerns it may be preferable to liberalise such industries.

1.3 Liberalisation and Regulation

There are many benefits from liberalisation or the potential liberalisation of an industry.[7] Prices will be forced towards realised avoidable costs bringing benefits for consumers. Under Bertrand competition with homogeneous products, if one or more firms enter the industry to compete with the incumbent, competition will bring prices in line with marginal cost and there will be zero profits. Under Cournot competition there remains a positive mark-up of prices over costs, but free-entry ensures that the firms only earn normal profits. Liberalisation and competition will improve pro-

[7] For an in depth discussion of the issues concerning liberalisation of an industry and its relationship with regulation see Armstrong, Cowan and Vickers (1996).

ductive efficiency by weeding out high-cost firms. A competitive auction process is a useful way of illustrating this effect.[8] Suppose that there are n risk-neutral producers in an industry competing for the right to produce a single unit of output. Their costs are uniformly distributed on the unit interval $[0, 1]$. The contract is awarded to the producer who offers the lowest price to consumers. In a second price sealed-bid auction (Vickrey (1961)) the dominant strategy is for each firm to bid their true cost and therefore the contract will be awarded to the most efficient firm. As the number of potential producers tends to infinity the equilibrium cost and price will tend to zero, achieving productive efficiency. Liberalisation may also foster stronger incentives to invest in new processes and new products. Scherer (1967) models the problem of R & D expenditures as a Cournot game and shows that atomistic competition creates the strongest incentives for innovation.

As asymmetric information is one of the main causes of regulatory failure liberalisation can improve the effectiveness of regulation. The existence of firms with similar cost characteristics increases the information available to regulatory agencies and enhances the power of incentive schemes. This is closely related to the theory of yardstick competition. The basic idea is to induce competition between several regional monopolies via the regulatory process and thereby to reduce firms' informational rents. This is achieved by making the reward of any given firm dependent on its performance relative to that of other firms in the industry. Demski and Sappington (1984) and Shleifer (1985) show that, under certain assumptions about firms' costs, yardstick competition may be used to compete away firms' informational rents thereby realising the first-best level of welfare.

Potential liberalisation may also strengthen regulatory incentive schemes. Caillaud (1990) modifies the Baron-Myerson model to allow a competitive fringe of firms to compete with the regulated incumbent ex-post. He shows that, if their costs levels

[8] For a detailed guide to the auction literature and potential applications consult McAfee and McMillan (1987) or Klemperer (1999a,b).

are correlated, the threat of entry will reduce the level of informational rents acquired by the regulated firm and may raise or lower the distortion in the regulated firm's pricing policy.

Liberalisation may have significant effects on the investment incentives of regulated firms. Biglaiser and Ma (1999) consider the effect on investment incentives and social welfare of allowing a single entrant into a previously monopolistic industry. They assume that the entrant is a Stackelberg follower and therefore reacts to the regulated firm's quantity. Partial liberalisation has an ambiguous effect. If investment reduces the incumbent's virtual cost liberalisation will increase the marginal incentive to invest. Social welfare improves because of lower prices and higher investment. Otherwise there will be a trade-off between greater competition and lower prices for consumers and a lower level of investment by the regulated firm.

There are, however, a number of factors that may hinder the development of effective competition in an industry. While in theory Bertrand competition with homogeneous products results in allocative efficiency, in practice, if there are any fixed costs, firms will choose not to enter the industry. Limit pricing by established firms may also discourage entry. Milgrom and Roberts (1982) show that, under incomplete information, the pre-entry price may be considered as a signal regarding the incumbent's costs. As these are in turn determinants of the entrant's post-entry profits low prices may discourage entry. If established firms have privileged access to essential inputs to the production process or are the sole supplier of such inputs they may be able to deny their rivals fair access. For example, vertically integrated firms may charge uncompetitive prices for bottleneck inputs such as network access.[9] In all such cases liberalisation may be ineffective, resulting in limited competition or an unregulated monopoly. Moreover there may be welfare costs resulting from successful entry. Free-entry may lead to the duplication of fixed set-up costs. Mankiw and

[9] There is an extensive literature on access pricing and on the issue of whether vertical integration or vertical separation is preferable. See, for example, Armstrong, Doyle, and Vickers (1996), Laffont and Tirole (1994) and Vickers (1995).

Whinston (1986) examine the free-entry equilibrium for a variety of market structures and show that there is generally excess entry into the industry. The excess entry result may be reversed if product differentiation is introduced or if a low weight is given to profits in the social welfare function. Successful liberalisation may also cause problems of cream-skimming. New entrants compete for the firm's most profitable business leaving the remaining services unsustainable.

The suitability of policies aimed at liberalising an industry ultimately depends on how they compare with the possibility of continued regulation. The main contribution of Chapter 4 is to extend the Baron-Myerson framework to allow the monopolist the choice of whether or not to liberalise the industry. I thus determine endogenously the conditions under which it is preferable to liberalise an industry rather than to maintain a regulated monopoly. I assume that there are an infinite number of potential entrants with the same technology as the incumbent. If entry takes place the firms compete under Cournot competition. I find that if marginal costs are unobservable and there are very strong natural monopoly conditions or the regulator places a high weight on profits it is never optimal to liberalise. Monopoly regulation avoids the duplication of fixed costs and associated informational rents are relatively low. More generally it is optimal to maintain a regulated monopoly for low realisations of costs and to liberalise for high realisations. By contrast, if fixed costs are unobservable and are uniformly distributed, it is never optimal to liberalise the industry. Chapter 4 differs from previous work comparing monopoly regulation and liberalisation as it considers complete liberalisation of the industry rather than simply allowing a single entrant into the market. Furthermore the choice of industry structure is endogenously determined. I show that there are many circumstances under which it is desirable to maintain monopoly regulation.

An alternative application of the model in Chapter 4 is used to consider the effect of regulatory capture on entry decisions. When marginal costs are unknown entry is distorted upward relative to the efficient level. In general it is optimal to regulate entry for low observations of costs and to allow free-entry for high realisations of costs.

In conclusion the design of regulatory institutions remains a complex task given such constraints as asymmetric information, problems of commitment and under-investment, and regulatory capture. In light of these problems this thesis aims to examine a number of relevant issues concerning privatisation, regulation and liberalisation. Chapters 2 and 3 explore the regulatory commitment problem. I consider the optimal level of commitment for a regulator of a firm with market power and show that partial privatisation is effectively a form of commitment to higher regulated prices. Given the limitations of regulatory policy it may be preferable to liberalise an industry. Chapter 4 compares liberalisation with the alternative of continued regulation of a monopolistic firm and determines the conditions under which it is optimal to liberalise. Chapter 5 concludes.

Chapter 2

The Optimal Level of Regulatory Commitment

2.1 Introduction

An important issue concerning the regulation of firms with market power is how much, if any, discretion should be given to the regulator. On the one hand, the regulator must have flexibility to adapt to changing conditions, such as shifts in technology and demand, but equally there must be stability for investors to be confident of a reasonable return on their investments. Regulation is delegated to regulatory institutions because they have an informational advantage, they are required to pursue objectives other than those of the government or because the government is politically constrained. However, limits on discretion may be required to create stability and to prevent the regulator from straying too far from the government's optimal policies.

This issue arises from the incompleteness of contracts. Given full information, complete contracts and benevolent policy-makers economic efficiency could be achieved. In practice asymmetric information, the need for credible commitment and danger of regulatory capture mean that careful institutional design is critical for performance.

The traditional literature on investment incentives for regulated firms emphasises the Averch-Johnson (1962) overinvestment effect. If the allowed rate of return exceeds the cost of capital, the firm will maximise profits by over-expanding its capital base. However, in the absence of regulatory credibility *underinvestment* is the main concern.

Network utilities are characterised by high levels of sunk costs leaving the regulator wide scope for opportunism once investments have been made. It is in the interest of consumers for the regulator to reduce prices in line with avoidable costs ex-post. Unless a regulator can credibly commit not to deviate from its announced policies many important investments will not be made.

A related problem for investment incentives is the 'ratchet effect'. Laffont and Tirole (1993, ch. 9) show that if a firm produces output at a low cost, the regulator may infer that low costs are easy to achieve and therefore tighten its incentive scheme. The firm may lose future informational rents by undertaking high levels of investment.

The costs to the utilities of regulatory rule changes may be substantial. Houston (1998) estimates the cost of rule changes in the UK between 1984 and 1998, including the windfall tax, to have been approximately £13 billion. An increase of 2-3 percentage points in the required rate of return would be needed to offset the cost of such changes.

Underinvestment has been particularly severe in some of the transitional economies. Armstrong and Vickers (1996) discuss how the absence of credible legal institutions and systems of contract law, combined with a history of low tariffs have acted to intensify the credibility problem in the telecommunications sector in Central and Eastern Europe (CEE). Difficulties with excess demand, low coverage and outdated technology mean that it is vital that adequate investment takes place. Newbery (1994) argues that the electricity industries of CEE countries are particularly vulnerable to opportunism by their regulators as they have high levels of sunk costs, and investors cannot inflict much damage in the event of a regulatory breakdown. The consequences of holding back investment are small, as domestic capacity will outstrip demand until the end of the century.

There are a number of ways in which credibility can be strengthened, thereby increasing incentives for investment. Reputational effects may deter regulatory opportunism. The regulator will resist the temptation to make ex-post revisions of policy if the future costs from a loss of credibility exceed the short-run gains. With a short-term relationship agreements between the regulator and the firm will usually collapse with the result that there is little or no investment. However, with an infinite horizon many superior outcomes for investment can be sustained. Salant and Woroch (1992) show that if each party can credibly threaten to punish the other severely in the event of a deviation from their announced strategies, a near efficient level of investment can be sustained.

The costs of a loss of reputation are more substantial if foreign capital is considered. Jones (1993) suggests that the risk of expropriation may be reduced by implementing appropriate conditions in borrowing agreements with other countries or international institutions. For example, they may call for restricted access to future borrowing or seizure of bonds which have been posted as security in response to ex-post regulatory changes.

Wider share ownership will place important political constraints on expropriating rents. Vickers (1991) notes that if the public have a large proportion of the shares in the utilities they may oppose renationalisation or a tightening of price controls.

The capital structure of the firm can have significant effects on the regulator's commitment power. A utility can reduce the regulator's incentive to act opportunistically by strategically issuing debt. Spiegel and Spulber (1994) show that if a regulator aims to maximise consumer surplus minus bankruptcy costs, it is not in its interest to ratchet prices down when the firm is highly levered.

Strong institutional structures are a key factor in developing regulatory credibility. Levy and Spiller (1994) investigate telecommmunications regulation in five countries and conclude that three types of restraint are necessary for credible regulation. Firstly, there must be "substantive restraints" on the discretion of the regulator. Secondly, there should be "procedural restraints" on revising the regulatory regime. In the UK this has been achieved by embedding regulation in licenses, though this still leaves open the possibility of arbitrary legislative intervention, such as windfall taxes.

Finally, there must be strong legal institutions to enforce these restraints.

Clearly, the type of regulatory regime plays a vital role in determining the credibility of policies. While in principle "RPI-X" price-cap regulation provides strong incentives for cost reduction, the regulator may find it difficult to commit to the level of the cap. If it is perceived that the utility is earning excess profits, there will be strong political pressure for the regulator to undertake a price review. As a consequence there is a tendency for price-caps to be tightened over time, thereby approximating rate-of-return regulation. Mayer and Vickers (1996) suggest that profit-sharing regulation may not be the appropriate solution to this problem. Suppose that costs follow a random walk. If credibility depends on the variance of accumulated excess profits, then a profit-sharing regime turns out to be less credible than a price-cap regime. A better alternative may be to limit the regulator's discretion by guaranteeing a fair rate of return on 'used and useful' capital. Gilbert and Newbery (1994) show that such a regime can sustain efficient investment in a wider range of circumstances than traditional of return regulation. By enforcing a minimum rate-of-return on capital that is actually used, it limits the regulator's gain from opportunistic behaviour and thereby enhances credibility.

High levels of investment can therefore be sustained with the appropriate institutional conditions and careful choice of policy regime, but this often means sacrificing the flexibility to adapt to changing conditions. Regulatory discretion is particularly important where there are rapidly changing or uncertain levels of demand and costs, or where the regulator is better informed than the government. In such cases tightly-defined rules-based regulation may confer excess profits or substantial losses on the firm. Nevertheless there are a number of reasons why it may be desirable to limit regulatory discretion. The regulator may depart from the government's ideal policies because of ex-post opportunism, regulatory capture, or because its preferences differ from those of the government. Restrictions on discretion may also be useful in creating stability for investors. Armstrong (1995) discusses the desirable limits to discretion when a principal delegates decision-making to an agent with unknown preferences. The appropriate level of discretion trades off the benefits of flexibility against the danger that the agent will pursue undesirable policies. He finds that the greater the likelihood of the agent's preferences matching those of the principal, the more discretion should be granted to the agent.

I am interested in the trade-off between the need for commitment to policies to stimulate investment and the need for discretion in a rapidly changing environment. High levels of commitment give strong incentives for cost reduction and therefore for productive efficiency. However they weaken the regulator's ability to bring prices in line with costs and therefore reduce allocative efficiency. Armstrong, Rees, and Vickers (1995) show in their dynamic model of optimal regulatory lag under price-cap regulation that long regulatory lags give the firm stronger incentives to invest. However, this means prices are allowed to diverge from costs for longer periods, thereby reducing allocative efficiency.

In this chapter, which could be viewed as a kind of static version of Armstrong, Rees, and Vickers, I model the optimal level of regulatory commitment under imperfect information and therefore examine the factors that are important in determining the relative benefits of commitment and discretion. I assume that there is a monopoly firm facing known demand but uncertain costs. The regulator is unable to commit to the price that will be charged at the end of the period, but can commit to the price being within a chosen interval. A narrow interval for prices then implies a high level of commitment, whereas a wide interval implies a high level of discretion. I assume that the regulator chooses the interval of prices strategically to limit its own level of discretion and therefore to influence the firm's profit-maximising choice for investment.

In section 2.2 I develop a simple model where the regulator chooses between the polar cases of full discretion and full commitment over prices. This illustrates how the elasticity of demand, the level of uncertainty, and the cost of investment influence the relative benefits of commitment and discretion. In section 2.3 I determine the optimal level of commitment and show how each of the factors discussed in section 2.2 affect this solution. Finally, a summary of my results and final remarks are given in section 2.4.

2.2 Full Discretion or Full Commitment?

The regulator's ability to commit is derived from constitutional restrictions on the regulator's discretion. In the UK the government has limited regulators' discretion by embedding the regulatory regime in licenses. The regulated firms' licenses typically define the degree to which a regulator can intervene in investment and pricing decisions. For example Special Condition 9c of Transco's license defines the 1997-2002 price control. Changes to license conditions can only be made with the agreement of the relevant firm or through a reference to the Monopoly and Mergers Commission, which may very costly for all the parties involved. Levy and Spiller (1996) emphasise that "the existence of an independent judiciary with a strong tradition of upholding contracts and property rights allows regulatory bargains to be enforced through licensing arrangements".

The interaction between the regulator and the monopolistic firm is modelled as a one-period game. At the beginning of the period, the regulator chooses the interval of prices $[p_*\ ,\ p^*]$ from which it must eventually select the final price. This determines its level of ex-post discretion. For now, assume it selects one of two possible options: $p_* = 0$, $p^* = \infty$ (full discretion) or $p_* = p^* = \bar{p}$ (full commitment). The firm then decides whether or not to accept a contract, which binds it to produce, and decides how much to invest, based on its expectation of future profits. The game continues as follows: both the regulator and the firm observe marginal operating costs and the regulator decides the price at which the firm may sell its product. Finally, the firm produces and sells its output in the market.

The firm faces a demand function $q(p)$, where $q'(p) < 0$. The marginal operating cost c is constant and equal to $\theta - e$, where θ is the efficiency parameter and e is the level of sunk cost-reducing capital. θ has a distribution with mean $\overline{\theta}$, and support $[\overline{\theta} - \delta \ , \overline{\theta} + \delta]$. The cost of capital is given by the function $\psi(e) = \frac{d}{2}e^2$. The marginal cost c is observable but not verifiable, and neither θ nor the level of e can be observed. The regulator therefore cannot set a contract which conditions the price on the level of θ, c, or e.

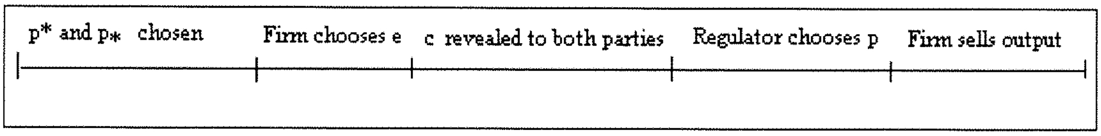

Figure 2.1: Move Order

The regulator and firm both seek to maximise the expected value of their objective functions (social welfare and profits respectively) which are shown below:

$$W_R = V(p) + \Pi(p). \tag{2.1}$$

$$\Pi(p) = q(p)(p - \theta + e) - \psi(e).$$

The regulator's objective function is the unweighted sum of consumer and producer surplus. $V(p)$ is consumer surplus at price p. It satisfies $V'(p) = -q(p)$ where $V'(p)$ is the derivative of $V(p)$.

Imperfect information is modelled by assuming that neither the firm nor the regulator is informed as to the value of θ until after investment takes place. The optimal strategy is therefore the same for all firms, regardless of their true θ-value. This yields a simpler solution than the case where the firm has private information as to the true value of θ, as more efficient firms are unable to gain rents by mimicking less efficient types.

There are two effects which must be traded off:

- Productive Efficiency. Higher levels of investment require greater commitment to prices.

- Allocative Efficiency. Flexibility is necessary for the regulator to adjust prices in line with realised costs and thereby to maximise consumer surplus.

I shall firstly consider the solution where the regulator has full discretion. This holds where $[p_* \ , \ p^*] = [0 \ , \ \infty]$. The regulator has full discretion to choose prices ex-post, and therefore sets the price equal to marginal operating costs. Anticipating this, the forward-looking firm undertakes no investment and there is an inefficient solution: $p = \theta$, $e = 0$, $\psi(e) = 0$, and $\Pi = 0$. The regulator's welfare is simply the expected level of consumer surplus:

$$W_{FD} = E_\theta V(\theta). \tag{2.2}$$

I turn next to the case of full commitment. This holds where $p_* = p^* = \overline{p}$. The regulator has no discretion over the price ex-post, so the firm receives the full return from its cost-reducing investments. The regulator chooses $\bar{p}$ to maximise its welfare, W_R, subject to meeting the firm's break-even constraint $[q(\overline{p})(\overline{p} - \overline{\theta} + e)] - \psi(e) \geq 0$. Given increasing returns to scale average-cost pricing is optimal. If the price is greater than average cost, then it can be reduced slightly without the firm incurring losses. Given the welfare function defined in equation (2.1) welfare can always be improved by moving the price closer to marginal cost. With increasing returns to scale, price being greater than average cost implies that the price is greater than marginal cost. Welfare is therefore maximised by a price reduction which just allows the firm to break even. I have

$$\overline{p} = \overline{\theta} - \frac{q(\overline{p})}{2d}. \tag{2.3}$$

The price announcement must satisfy the following equation:

$$\overline{p} \leq \overline{\theta}. \tag{2.4}$$

Clearly, with the break-even constraint binding, the expected profit of the firm will be zero, so that the regulator's welfare is simply the level of consumer surplus $V(\overline{p})$.

To compare the outcomes under full commitment and discretion (W_{FC} and W_{FD} respectively) I derive the following result:

$$\begin{aligned} W_{FD} &= E_\theta V(\theta) \geq V(\overline{\theta}). \\ W_{FC} &= V(\overline{p}) \geq V(\overline{\theta}). \end{aligned} \tag{2.5}$$

Expected welfare under full discretion (W_{FD}) exceeds welfare from commitment to a fixed price of $\overline{\theta}$.[1] However, the optimal price under full commitment (as shown in 2.4) is less than or equal to $\overline{\theta}$. Either full commitment or full discretion may be optimal, depending on the cost of investment, the convexity of consumer surplus and the degree of uncertainty.

Full commitment is preferable for low levels of uncertainty.

$$\delta \approx 0 \Rightarrow W_{FD} \approx V(\overline{\theta}) < V(\overline{p}) = W_{FC}$$

For δ close to zero there is little uncertainty and therefore commitment to a fixed price only causes a small loss of consumer surplus. This loss is dominated by the gains from full commitment in the form of higher investment and lower prices. As δ increases, the convexity of consumer surplus means that allocative efficiency is improved if the regulator has the flexibility to adjust prices once costs are realised. For high levels of uncertainty full discretion is preferable.

Full commitment is preferable with inelastic demand.

$$\eta \approx 0 \Rightarrow W_{FD} \approx V(\overline{\theta}) < V(\bar{p}) = W_{FC},$$

[1] This obtains because of Jensen's inequality. For a strictly convex function, such as consumer surplus with elastic demand, the expectation of the function is greater than the function of the expectation.

where $\eta = -\frac{q'p}{q}$ is the elasticity of demand.

This holds because consumer surplus ceases to be strictly convex in θ, and hence there is no loss of expected surplus from committing to a fixed price. As demand becomes more elastic consumer surplus becomes increasingly convex and the benefits of discretion increase. For high elasticities full discretion is preferable.

Full discretion is preferable for high costs of investment.

$$d \to \infty \Rightarrow W_{FC} \to V(\overline{\theta}) < E_\theta V(\theta) = W_{FD}$$

As the cost of investment increases the optimal price under full commitment tends towards the mean efficiency paramter $\overline{\theta}$ (the second term in equation (2.3) tends to zero) and the benefits of commitment tend to zero. For a sufficiently high cost full discretion is preferable.

These trade-offs are examined in greater detail in the following example.

2.2.1 Example with linear demand and a uniform distribution

I shall determine the solutions for the regulator's expected welfare with a linear demand function, $q(p) = \alpha - \beta p$, and a uniform distribution. I assume $\alpha, \beta > 0$. θ is uniformly distributed on $[\overline{\theta} - \delta \ , \ \overline{\theta} + \delta]$. Consumer surplus, $V(p)$, is calculated by integrating $V'(p) = -q(p)$.

$$V(p) = \int_p^{\frac{\alpha}{\beta}} (\alpha - \beta\widetilde{p})d\widetilde{p} = \frac{1}{2\beta}(\alpha - \beta p)^2.$$

From equation (2.5) it is clear that the optimal level of welfare under full discretion is equal to $E_\theta V(\theta)$. I now calculate this expectation using the uniform distribution:

$$\begin{aligned} W_{FD} &= E_\theta V(\theta) = \frac{1}{4\beta\delta}\int_{\overline{\theta}-\delta}^{\overline{\theta}+\delta} (\alpha - \beta\theta)^2 \cdot d\theta \\ &= \frac{1}{2\beta}(\alpha - \beta\bar{\theta})^2 + \frac{\beta}{6}\delta^2 = V(\bar{\theta}) + \frac{\beta}{6}\delta^2. \end{aligned}$$

The final term in this equation is the benefit from discretion. (i.e. the increase in expected surplus owing to the convexity of the consumer surplus function.)

Turning next to the case of full commitment, I derive the optimal price and then substitute this back into the regulator's welfare function in order to find the optimal level of welfare. The optimal price, $\bar{p}$, is found by substituting $q(p) = \alpha - \beta p$ into equation (2.3) and then solving for $\bar{p}$:

$$\bar{p} = \frac{2d\bar{\theta} - \alpha}{2d - \beta}$$

The optimal level of welfare under full commitment is therefore

$$W_{FC} = V(\bar{p}).$$

In order to ensure the existence of this equilibrium two conditions must obtain (as illustrated in Figure 2.2 below). $\frac{\alpha}{\beta} > \overline{\theta}$ (the vertical intercept of the demand curve lies above that for the average cost curve) and $2d\overline{\theta} > \alpha$ (the horizontal intercept of the average cost curve lies to the right of that for the inverse demand curve). These are in turn sufficient conditions for $\bar{p}$ to be positive and less than or equal to $\overline{\theta}$.

For full commitment to be preferable to full discretion the following inequality must obtain

$$V(\bar{p}) - V(\overline{\theta}) > \frac{\beta}{6}\delta^2.$$

Using the fact that the tangent to a convex function must always lie below the curve I derive the following result[2] :

$$V(\overline{p}) - V(\overline{\theta}) \geq -q(\overline{\theta}) \cdot (\overline{p} - \overline{\theta}) = q(\overline{\theta}) \cdot (\overline{\theta} - \overline{p}) = \frac{(\alpha - \beta\overline{\theta})^2}{2d - \beta}.$$

A *sufficient* condition for full commitment to be preferable is that

$$\frac{6(\alpha - \beta\overline{\theta})^2}{\beta(2d - \beta)} > \delta^2. \tag{2.6}$$

[2] The optimal price under full commitment, $\overline{p}$, may be rewritten in the following form: $\overline{p} = \overline{\theta} - \frac{\alpha - \beta\overline{\theta}}{2d - \beta}$.

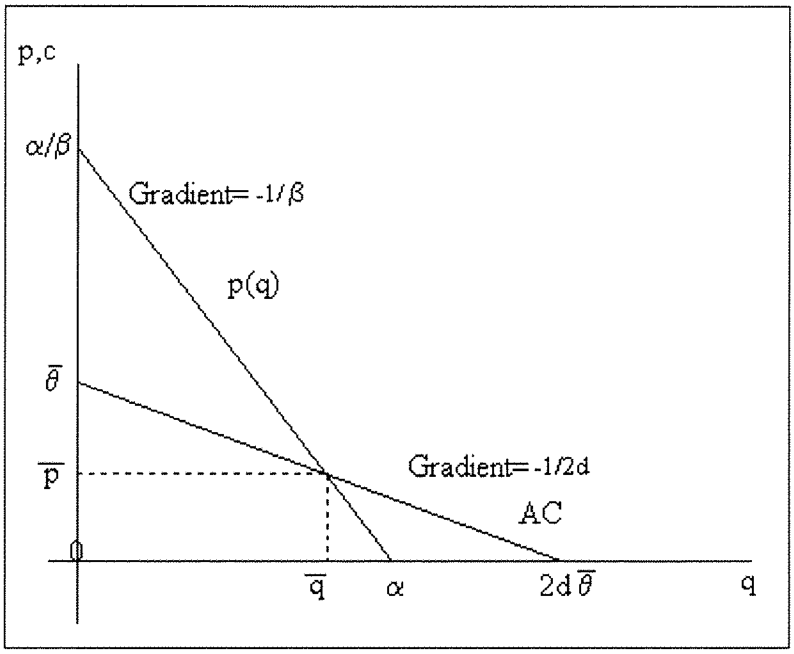

Figure 2.2: Full Commitment Equilibrium under Imperfect Information

This clearly shows that for low levels of uncertainty (δ small) and low elasticities (β small) concerns for productive efficiency dominate those for allocative efficiency and full commitment is optimal. When a regulator knows the future level of costs with a reasonable degree of accuracy it can commit to future prices without any significant loss of allocative efficiency. Its main concern is to encourage higher levels of investment. With relatively inelastic demand, even if costs are uncertain, the benefits of discretion are small relative to the potential gains from commitment. Investment will again be the primary concern.

2.3 The Optimal Level of Commitment

In section 2.2 I showed which factors were important in determining whether full commitment was preferable to full discretion. These were the costs of investment, the degree of uncertainty and the elasticity of demand. I shall now examine how these factors affect the optimal level of commitment. A high level of commitment provides strong incentives for investment, but also confers large rents on the firm. By contrast, a high level of discretion gives the regulator the freedom to adjust prices in line with realised costs, but only gives weak incentives for investment. The appropriate degree of commitment must trade off these two effects.

The interaction between the regulator and the monopoly is again modelled as a one-period game. At the beginning of the period, the regulator announces an interval of prices $[p_* \, , \, p^*]$ from which it must eventually select the final price. The firm then decides its level of slackness (the inverse of effort), based on its expectation of future profits. The game continues as follows: both the regulator and the firm observe marginal operating costs, and the regulator decides the price at which the firm may sell its product. Finally, the firm produces if prices are greater than or equal to realised costs and sells its output in the market.

In this model the firm can choose not to produce if the price falls below marginal cost. (In the previous model the firm chose whether or not to accept a contract which bound it to produce in the final stage of the game.) This is more realistic and simplifies our analysis considerably as it will be optimal for the regulator to set no upper bound for prices.

The firm faces unit demand at prices less than or equal to $\overline{p}$ (demand is zero for $p > \overline{p}$). The marginal operating cost is constant and equal to c, where I assume that if the level of slackness is S, then cost c is uniformly distributed on $[S - \delta \, , \, S + \delta]$.[3]

The cost of slackness is a sunk cost, which is decreasing in S and is given by the quadratic function, $\psi(S)$, where

$$\psi(S) = \frac{\omega}{2}S^2 - \tau S + \frac{\tau^2}{2\omega}.$$

I take $S = \dfrac{\tau}{\omega}$ to be the maximum level of slackness, which is equivalent to zero effort. $\psi(\dfrac{\tau}{\omega}) = 0$. I assume $\tau > 1$ and $2\delta\omega > 1$. The marginal cost c is observable but not verifiable and the level of slackness is not observed by the regulator. The regulator therefore cannot set a contract which conditions the price on the level of c or S.

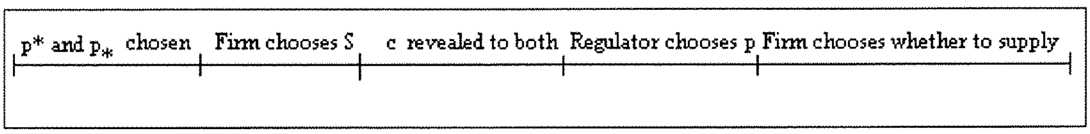

Figure 2.3: Move Order

The regulator and firm seek to maximise the expected value of their objective functions (a weighted-sum of consumer surplus and profits, and profits respectively), which are shown below:

$$W = \text{Consumer Surplus}+\gamma.\text{Profits} = [\overline{p} - p] + \gamma[\pi(p, c) - \psi(S)].$$

$$\text{Profits}=\pi(p, c) - \psi(S) = p - c - \psi(S),$$

where $\pi(p, c)$ is the firm's gross profits excluding the costs of slackness.

The analysis proceeds as follows:

- I derive the efficient solution for slackness and prices.

[3] Clearly it would be possible for marginal costs to be negative. However, I assume that the marginal cost of reducing slackness $(\tau - \omega S)$ is sufficiently large relative to the level of uncertainty (δ) for there only to be positive realisations of costs in equilibrium.

- I examine the case of imperfect information and show that the regulator will set no upper bound on prices. (i.e. $p^* \geq S + \delta$.). This allows me to define the optimal level of commitment.

- I then derive the firm's expected profit function and determine the profit-maximising level of slackness as a function of the lower bound on prices

- I derive the regulator's expected welfare function and solve for the optimal level of the lower bound, $\widehat{p}_*$, and the optimal level of commitment, $\widehat{C}$.

- Finally, I extend the model for isoelastic demand.

2.3.1 Efficient Solution for Slackness and Prices

Suppose that the regulator is able to offer the firm a subsidy, t, to cover its sunk costs and that slackness is fully contractible. The efficient regulatory policy maximises the regulator's expected welfare subject to meeting the firm's break-even constraint:

$$\max_{p,t,S} W^e = E_c\left\{[\overline{p} - p - t] + \gamma[p + t - c - \psi(S)]\right\} \text{ s.t. } E_c[p + t - c - \psi(S)] \geq 0.$$

$$\Rightarrow t^b = \frac{1}{2\omega},\ S^b = \frac{\tau - 1}{\omega},\ p^b = c.$$

For instance the regulator may offer the firm a subsidy t^b, and ask it to exert slackness S^b. If the firm accepts the contract and then increases slackness beyond S^b it suffers a large penalty. Full discretion is then optimal for the regulator. (i.e. $p_* = 0$, $p^* = \infty$.) It will always set the price equal to marginal operating costs ex-post. Setting any limits on discretion would give rents to the firm, while providing no gain in productive efficiency. In the following analysis the regulator is unable to offer the firm a subsidy, observe S, or commit to future prices. It can, however, commit to prices being within a chosen interval. In determining the optimal level of commitment the regulator therefore faces a trade-off between productive efficiency and giving rents to the firm.

2.3.2 No upper bound on prices

The regulator's decision can be reduced to the choice of the optimal lower bound for prices, p_*. If the regulator sets an upper bound on prices such as $p^* < S+\delta$, the firm will choose not to produce in states where costs are greater than the upper bound, and therefore where it would make a loss from producing. Expected profits for the firm will be then as follows (assuming $p_* \geq S-\delta$):

$$\begin{aligned} &\int_{p^*}^{S+\delta} 0 \cdot \frac{1}{2\delta} dc + \int_{p_*}^{p^*} 0 \cdot \frac{1}{2\delta} dc + \int_{S-\delta}^{p_*} (p_* - c) \cdot \frac{1}{2\delta} dc - \psi(S) \\ = &\int_{S-\delta}^{p_*} (p_* - c) \cdot \frac{1}{2\delta} dc - \psi(S). \end{aligned}$$

The firm does not produce in the upper interval and in the middle interval prices are equal to cost.

If, on the other hand, the regulator sets an upper bound which is greater than the highest possible realisation of costs (i.e. $p^* > S+\delta$), the firm produces in all states of the world. Expected profits will be:

$$\begin{aligned} &\int_{p_*}^{S+\delta} 0 \cdot \frac{1}{2\delta} dc + \int_{S-\delta}^{p_*} (p_* - c) \cdot \frac{1}{2\delta} dc - \psi(S) \\ = &\int_{S-\delta}^{p_*} (p_* - c) \cdot \frac{1}{2\delta} dc - \psi(S). \end{aligned}$$

The two expressions are identical showing that a binding upper bound has no effect on the firm's incentives to reduce costs and the chosen level of slackness. (The firm always has the option not to produce if prices are below costs.) However, the choice of an upper bound does affect the regulator's welfare. In states where no production takes place consumer surplus is equal to zero. An upper bound below $S+\delta$ causes no reduction in slackness, but reduces expected consumer surplus and expected welfare for the regulator. It is therefore optimal for it to set $p^* \geq S+\delta$ such that there is no upper limit on discretion. The regulator always sets prices sufficiently high for production to take place. The remaining decision is the appropriate level of the lower bound for prices, p_*.

I can now define the level of regulatory commitment as:

$$C(p_*) = \begin{cases} 0 & \text{if } p_* \leq S - \delta \\ \dfrac{p_* - (S - \delta)}{2\delta} & \text{if } S - \delta < p_* < S + \delta \\ 1 & \text{if } p_* \geq S + \delta \end{cases} . \tag{2.7}$$

If the lower bound for prices, p_*, is less than the lowest possible realisation of costs then there is full discretion. The regulator can always bring prices in line with realised costs. ($C(p_*) = 0$). If the lower bound for prices is greater than the highest possible realisation of costs there is full commitment. The regulator will simply set the price equal to p_* in the final stage of the game. ($C(p_*) = 1$.) For intermediate levels of p_* there is a limited level of commitment. There is an interval of costs over which the regulator will set the price equal to the lower bound, p_*. For higher costs it will set the price equal to the lower bound, p_*. ($0 < C(p_*) < 1$.)

2.3.3 Firm's Expected Profit Function

The firm's expected gross profits (excluding the costs of slackness) are given by

$$\pi^e(p_*) = \begin{cases} 0 & \text{if } p_* \leq S - \delta \\ \dfrac{1}{4\delta}(p_* - S + \delta)^2 & \text{if } S - \delta < p_* < S + \delta \\ p_* - S & \text{if } p_* \geq S + \delta \end{cases} .$$

This is derived from the regulator's optimal behaviour in the final stage of the game. If the lower bound for prices is less than or equal to the lowest possible realisation of costs ($p_* \leq S - \delta$), the regulator will always set the price equal to cost ex-post and gross profits will be equal to zero. If the lower bound is greater than or equal to the highest possible realisation of costs ($p_* \geq S + \delta$), the regulator will set the price equal to the lower bound p_*. Expected profits will be equal to the level of the lower bound minus the average cost, S. For an intermediate lower bound profits are equal to $\pi^e(p_*) = \frac{1}{2\delta}\int\limits_{S-\delta}^{p_*}(p_* - c)dc = \frac{1}{4\delta}(p_* - S + \delta)^2$. Both the profit function and its first derivative with respect to the lower bound are continuous.

Concavity is sufficient to ensure that the firm's objective function, $\pi^e(p_*, c) - \psi(S)$, is single-peaked in slackness. This in turn requires that $\tau > 1$ and $2\delta\omega > 1$. The firm's profit-maximising level of slackness is then obtained by differentiating its objective function with respect to S, and setting the first-order condition equal to zero. Figure 2.4 illustrates the first-order condition for the firm.

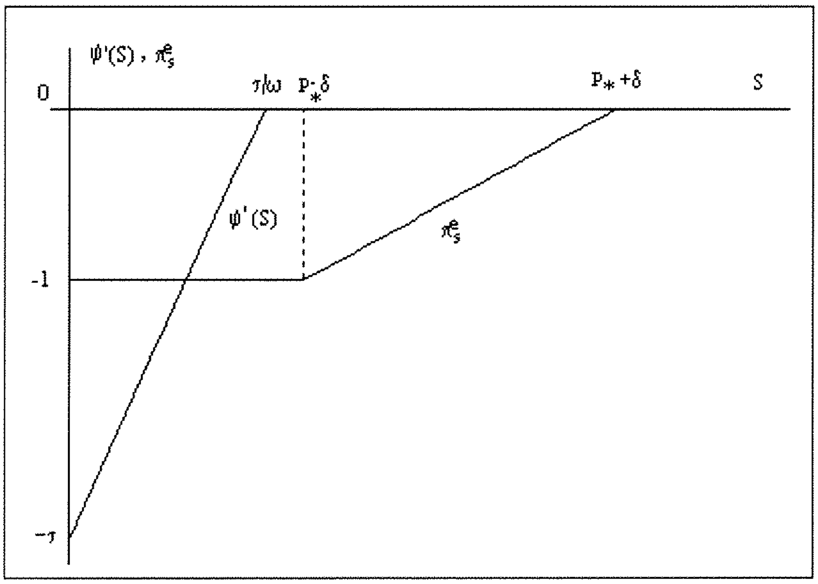

Figure 2.4: First-Order Condition for the Firm

$$\pi^e_S - \psi'(S) = \begin{cases} \tau - \omega S & \text{if } p_* \leq S - \delta \\ -\frac{1}{2\delta}(p_* - S + \delta) + \tau - \omega S & \text{if } S - \delta < p_* < S + \delta \\ -1 + \tau - \omega S & \text{if } p_* \geq S + \delta \end{cases} = 0$$

$$\Rightarrow S = \begin{cases} \frac{\tau}{\omega} & \text{if } p_* \leq \frac{\tau}{\omega} - \delta \\ \frac{2\delta\tau - p_* - \delta}{2\delta\omega - 1} & \text{if } \frac{\tau}{\omega} - \delta < p_* < \frac{\tau - 1}{\omega} + \delta \\ \frac{\tau - 1}{\omega} & \text{if } p_* \geq \frac{\tau - 1}{\omega} + \delta \end{cases}$$

The profit-maximising level of slackness, S, is constant in the lower bound, p_*, over the lower interval. The firm receives no return from its cost-reducing effort, and therefore maximises slackness. ($S = \dfrac{\tau}{\omega}$.) Slackness is decreasing in p_* over the middle interval for prices. The firm receives an increasing share of the returns from its efforts as p_* increases, and therefore the profit-maximising level of slackness is falling. Finally, slackness is constant over the upper interval. The firm receives the full return from its effort and therefore chooses the efficient level of slackness. This is illustrated in Figure 2.5.

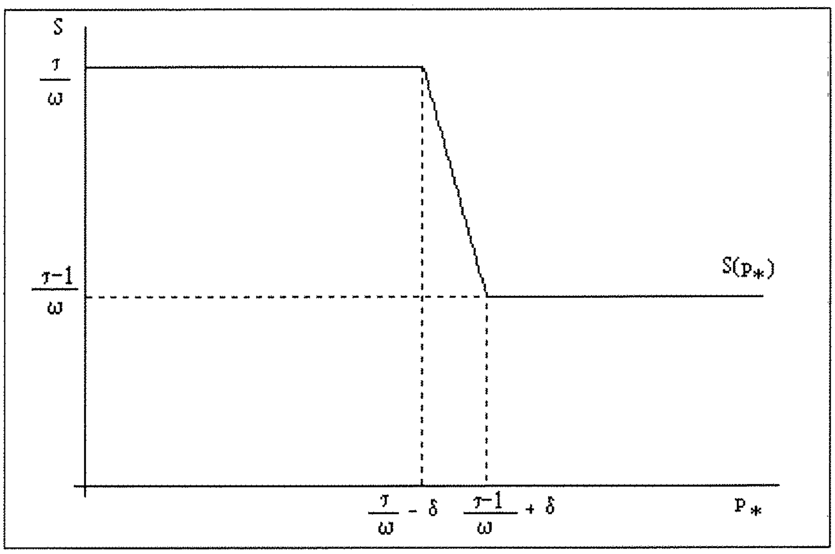

Figure 2.5: Solution for Slackness: Inelastic Demand

2.3.4 Regulator's Expected Welfare Function

The regulator's expected welfare is given by:

$$\begin{aligned} W^e(p_*) &= E_p[\overline{p} - p] + \gamma[\pi^e(p_*) - \psi(S)] \\ &= \begin{cases} \overline{p} - S - \gamma\psi(S) & \text{if } p_* \leq S - \delta \\ \overline{p} + \dfrac{1}{4\delta}(\gamma - 1)(p_* - S + \delta)^2 - S - \gamma\psi(S) & \text{if } S - \delta < p_* < S + \delta \\ \overline{p} + (\gamma - 1)p_* - \gamma S - \gamma\psi(S) & \text{if } p_* \geq S + \delta \end{cases} \end{aligned}$$

where $\psi(S) = \dfrac{\omega}{2}S^2 - \tau S + \dfrac{\tau^2}{2\omega}$. This is derived from the regulator's optimal behaviour in the final stage of the game and the firm's profit function. For $p_* \leq S - \delta$, the regulator will always set price equal to cost ex-post and hence expected welfare is simply $\overline{p}$ minus the average cost minus weighted costs of slackness. For $p_* \geq S + \delta$, the price will always be p_* ex-post, and hence the level of welfare is $\overline{p} - p_*$ plus weighted profits. For an intermediate lower bound expected welfare is equal to

$$\overline{p} - \frac{1}{2\delta}\left\{\int_{p_*}^{S+\delta} c.dc + \int_{S-\delta}^{p_*} p_*.dc\right\} + \gamma\pi(p_*) - \gamma\psi(S).$$

$W^e(p_*)$ and its first derivatives with respect to S and p_* are continuous functions.

2.3.5 Solution

I have already determined the profit-maximising level of slackness. The next step is to substitute this solution back into the regulator's expected welfare function:

$$W^e(p_*) = \begin{cases} \overline{p} - \frac{\tau}{\omega} & \text{if } p_* \leq \frac{\tau}{\omega} - \delta \\ \overline{p} + \frac{1}{4\delta}(\gamma - 1)(p_* - \widetilde{S} + \delta) - \widetilde{S} - \gamma\psi(\widetilde{S}) & \text{if } \frac{\tau}{\omega} - \delta < p_* < \frac{\tau - 1}{\omega} + \delta \\ \overline{p} + (\gamma - 1)p_* - \frac{\gamma}{2\omega}(2\tau - 1) & \text{if } p_* \geq \frac{\tau-1}{\omega} + \delta \end{cases}$$

where $\widetilde{S} = \dfrac{2\delta\tau - p_* - \delta}{2\delta\omega - 1}$.

$W^e(p_*)$ is a continuous function and is differentiable almost everywhere.[4] The first and second-order conditions for the regulator are found by differentiating $W^e(p_*)$ successively with respect to p_*.

$$W^e_{p_*} = \begin{cases} 0 & \text{if } p_* < \frac{\tau}{\omega} - \delta \\ \dfrac{\omega(p_* - \frac{\tau}{\omega} + \delta)(2\delta\omega(\gamma - 1) - \gamma) + 2\delta\omega - 1}{(2\delta\omega - 1)^2} & \text{if } \frac{\tau}{\omega} - \delta < p_* < \frac{\tau-1}{\omega} + \delta \\ \gamma - 1 \leq 0 & \text{if } p_* \geq \frac{\tau-1}{\omega} + \delta \end{cases} \tag{2.8}$$

$$W^e_{p_*p_*} = \begin{cases} 0 & \text{if } p_* < \frac{\tau}{\omega} - \delta \\ \dfrac{\omega(2\delta\omega(\gamma - 1) - \gamma)}{(2\delta\omega - 1)^2} \leq 0 & \text{if } \frac{\tau}{\omega} - \delta < p_* < \frac{\tau-1}{\omega} + \delta \\ 0 & \text{if } p_* > \frac{\tau-1}{\omega} + \delta \end{cases}$$

[4] The left-hand first derivative of $W(p_*)$ at $p_* = \dfrac{\tau}{\omega} - \delta$ is 0. The right-hand derivative at this point is $\dfrac{1}{2\delta\omega - 1} > 0$. The left and right-hand second derivatives are also different at $p_* = \dfrac{\tau}{\omega} - \delta$ and $p_* = \dfrac{\tau - 1}{\omega} + \delta$. This does not pose any problems for the model.

Expected welfare is constant in p_* over the lower interval, as the price is always set equal to marginal cost and the firm has no incentive to reduce slackness. It is then concave in p_* over the middle interval, reflecting the trade-off between productive efficiency and conferring rents on the firm.[5] Finally, expected welfare is decreasing in p_* over the upper interval, as extra rents are conferred on the firm without any further increases in productive efficiency. $W^e(p_*)$ therefore has the shape shown in Figure 2.6 and the optimal level of p_* must lie in the middle interval.

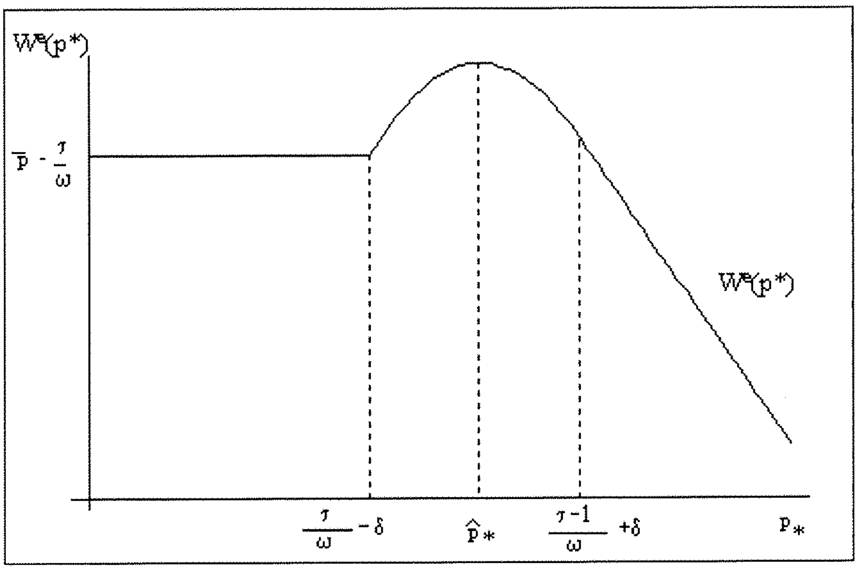

Figure 2.6: Graph of $W^e(p_*)$

The optimal level of the lower bound, p_*, is derived by setting the first-order-condition for the middle-interval in equation (2.8) equal to zero.

$$\widehat{p_*} = \frac{\tau}{\omega} + \frac{2\delta\omega - 1}{\omega(2\delta\omega(1-\gamma)+\gamma)} - \delta. \tag{2.9}$$

The optimal level of slackness is then found by substituting equation (2.9) into the slackness function.

$$\widehat{S} = \frac{\tau}{\omega} - \frac{1}{\omega(2\delta\omega(1-\gamma)+\gamma)} \geq \frac{\tau - 1}{\omega}. \tag{2.10}$$

[5] The right-hand first derivative of $W(p_*)$ at $p_* = \frac{\tau}{\omega} - \delta$ is positive and the second derivative is non-positive over this interval.

The optimal level of slackness is greater than or equal to the efficient level ($S^b = \frac{\tau - 1}{\omega}$). With imperfect information some productive efficiency is sacrificed in order to reduce the level of rents accruing to the firm. Finally, the optimal levels of regulatory commitment and expected welfare are found by substituting equations (2.9) and (2.10) into the commitment function and the regulator's objective function.

$$\widehat{C} = \frac{1}{(2\delta\omega(1-\gamma)+\gamma)}.$$

$$\widehat{W^e} = \overline{p} - \frac{\tau}{\omega} + \frac{1}{2\omega(2\delta\omega(1-\gamma)+\gamma)}. \tag{2.11}$$

The optimal levels of commitment and slackness are functions of the weight on profits in the regulator's objective function. The optimal level of commitment, $\widehat{C}$, is increasing in γ, while the optimal level of slackness, $\widehat{S}$, is decreasing. If the regulator places equal weight ($\gamma = 1$) on consumer surplus and profits, the efficient outcome is optimal. ($\widehat{S} = \frac{\tau - 1}{\omega}$.) Changes in p_* simply transfer surplus between the consumer and the firm, so the regulator maximises productive efficiency by choosing full commitment. ($\widehat{p}_* \geq \frac{\tau - 1}{\omega} + \delta$ and $\widehat{C} = 1$.) This case is illustrated in Figure 2.7.

For $\gamma < 1$, there are deadweight losses from increasing p_* and therefore the regulator retains some discretion. ($\widehat{p}_* < \frac{\tau - 1}{\omega} + \delta$ and $\widehat{C} < 1$.) This case is illustrated in Figure 2.8.

For $\gamma = 0$ (i.e. when the regulator is only concerned with consumer surplus) the solutions for $\widehat{p}_*$, $\widehat{S}$, $\widehat{C}$, and $\widehat{W^e}$ may be simplified as follows:

$$\widehat{p}_* = \frac{\tau + 1}{\omega} - \frac{1}{2\delta\omega^2} - \delta. \tag{2.12}$$

$$\widehat{S} = \frac{\tau}{\omega} - \frac{1}{2\delta\omega^2}. \tag{2.13}$$

$$\widehat{C} = \frac{1}{2\delta\omega}. \tag{2.14}$$

$$\widehat{W^e} = \overline{p} - \frac{\tau}{\omega} + \frac{1}{4\delta\omega^2}. \tag{2.15}$$

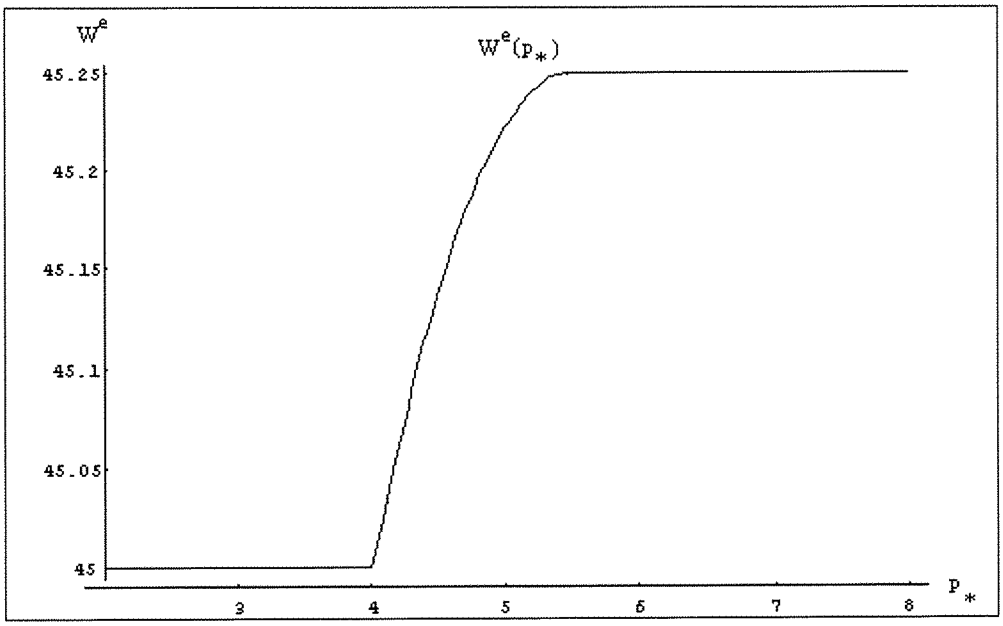

Figure 2.7: $W^e(p_*)$ for $\gamma = 1$, $\overline{p} = 50$, $\tau = 10$, $\omega = 2$, $\delta = 1$

The optimal level of the lower bound, $\widehat{p}_*$, may be increasing or decreasing in the level of uncertainty. There is a trade-off between two effects: Firstly, as the level of uncertainty increases, a higher lower bound is required to sustain a given level of investment (to prevent slackness from increasing). Secondly, a higher lower bound becomes more costly due to greater variation in costs. For $\delta < \dfrac{1}{\sqrt{2\omega}}$ the first effect dominates and $\widehat{p}_*$ is increasing in the level of uncertainty. For $\delta > \dfrac{1}{\sqrt{2\omega}}$, $\widehat{p}_*$ is decreasing.

The optimal level of the lower bound, $\widehat{p}_*$, is increasing in the costs of investment. Taking τ as fixed, a fall in ω represents an increase in the marginal cost of reducing slackness or equivalently an increase in the cost of investment. As ω falls the regulator must increase the lower bound on prices to sustain a given level of investment.[6]

The optimal level of slackness is increasing in the level of uncertainty. The second term in equation (2.13) is declining in δ and therefore $\widehat{S}$ is increasing. An increase in δ reduces the marginal benefit of reducing slackness relative to the marginal cost, so

[6] The derivative of the optimal lower bound with respect to ω is $\dfrac{d\widehat{p}_*}{d\omega} = \dfrac{1}{\delta\omega^3} - \dfrac{1+\tau}{\omega^2} < 0$.

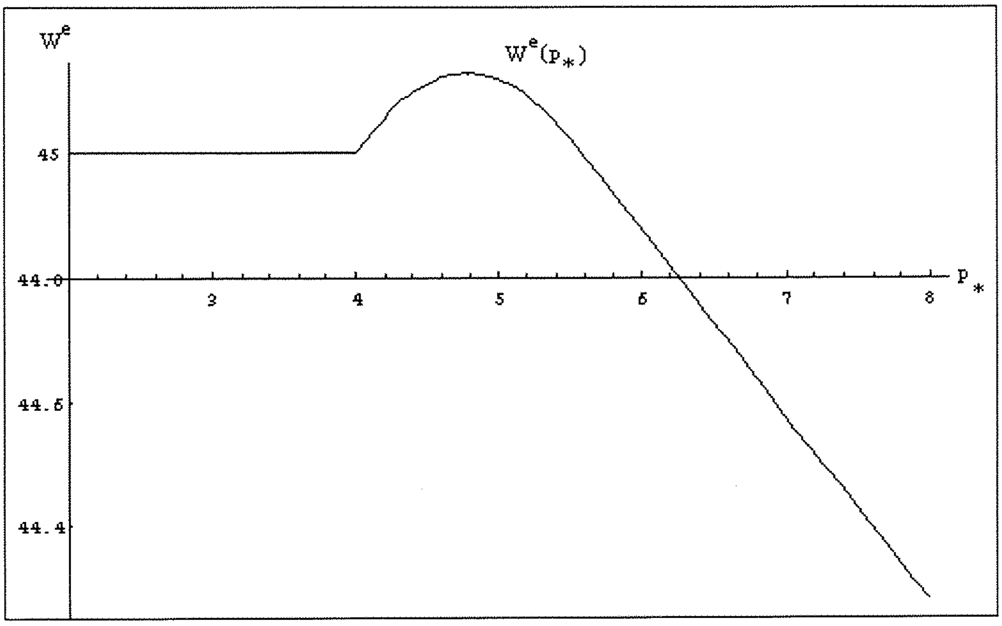

Figure 2.8: $W^e(p_*)$ for $\gamma = 0.7$, $\overline{p} = 50$, $\tau = 10$, $\omega = 2$, $\delta = 1$

the optimal level of slackness must rise.

The optimal level of slackness is decreasing in ω. Clearly, as the costs of reducing slackness fall relative to the benefits, the optimal level of slackness decreases.

The optimal level of regulatory commitment, $\widehat{C}$, is decreasing in the level of uncertainty. As the level of uncertainty increases there are greater benefits from the regulator being able to adjust prices in line with realised costs.

The optimal level of regulatory commitment, $\widehat{C}$, is increasing in the costs of investment. As ω falls a higher level of commitment is needed to sustain a given level of investment.

Finally, the optimal level of welfare is declining in the costs of reducing slackness and the level of uncertainty.

2.3.6 Extension for Elastic Demand

In section 2.2 I found that the elasticity of demand influenced the choice between full discretion and full commitment. In this section I shall introduce an isoelastic demand function and consider the effects of changes in elasticity on the optimal level of commitment.

The firm faces isoelastic demand, $q(p) = kp^{-\eta}$, with elasticity η for prices less than or equal to $\overline{p}$. (For $p > \overline{p}$ demand is equal to zero.) The profit function (excluding costs of slackness) is derived as for the inelastic case:

$$\pi^e(p_*) = \begin{cases} 0 & \text{if } p_* \leq S - \delta \\ \dfrac{k(p_* - S + \delta)^2}{4\delta p_*^\eta} & \text{if } S - \delta < p_* < S + \delta \\ \dfrac{k(p_* - S)}{p_*^\eta} & \text{if } p_* \geq S + \delta \end{cases}.$$

Concavity is sufficient to ensure that the firm's objective function, $\pi(p_*) - \psi(S)$, is single-peaked in slackness. This in turn requires that $2\omega\delta p_*^\eta - k > 0$ in the middle interval. The firm's profit-maximising level of slackness may then be found by differentiating its objective function with respect to S, and setting the first-order condition equal to zero:

$$S(p_*) = \begin{cases} \dfrac{\tau}{\omega} & p_* < \dfrac{\tau}{\omega} - \delta \\ \dfrac{2\delta\tau - kp_*^{-\eta}(p_* + \delta)}{2\delta\omega - kp_*^{-\eta}} & \dfrac{\tau}{\omega} - \delta < p_* < \mu \\ \dfrac{\tau - kp_*^{-\eta}}{\omega} & p_* > \mu \end{cases}, \tag{2.16}$$

where μ is the upper limit of the middle interval. (μ is the solution to $p_* = \dfrac{\tau - kp_*^{-\eta}}{\omega} + \delta$ for $2\omega\delta p_*^\eta - k > 0$.) The solution for slackness is continuous, as illustrated in Figure 2.9. Over the upper interval $S(p_*)$ is increasing in p_*. (This is in contrast with Figure 2.5 where $S(p_*)$ is constant.) As p_* increases, demand falls reducing the incentives to cut slackness. As p_* becomes large, the profit-maximising level of slackness tends towards $\dfrac{\tau}{\omega}$, equivalent to zero effort. (For the inelastic case changes in p_* over this interval have no effect on the incentives for slackness.)

The welfare function for the regulator is a weighted sum of consumer surplus and profits. The consumer surplus function is calculated by integrating the isoelastic

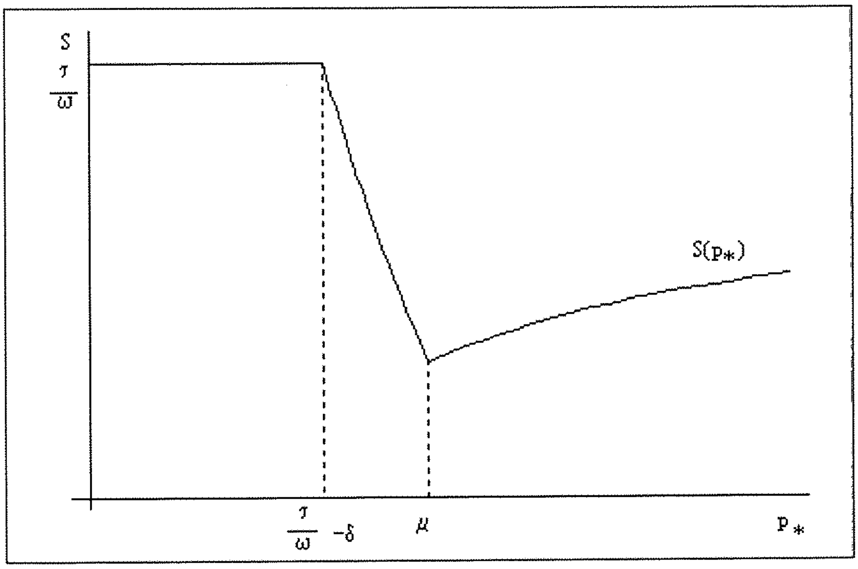

Figure 2.9: Solution for Slackness: Elastic Demand

demand function.

$$V(p) = \int_{p}^{\overline{p}} k\widetilde{p}^{-\eta} d\widetilde{p} = \left[\frac{k}{1-\eta}\widetilde{p}^{1-\eta}\right]_{p}^{\overline{p}} = \frac{k}{1-\eta}(\overline{p}^{1-\eta} - p^{1-\eta})$$

for $0 \leq \eta < 1$ and $\eta > 1$, and

$$V(p) = k(\ln \overline{p} - \ln p)$$

for $\eta = 1$. Expected consumer surplus can then be calculated by integrating over each of the intervals. Equation (2.17) shows the calculation for the lower interval, assuming $\eta \neq 1$.

$$\begin{aligned} V^e(p_*) &= \frac{k}{2\delta(1-\eta)} \int_{S-\delta}^{S+\delta} (\overline{p}^{1-\eta} - c^{1-\eta}) dc \\ &= \frac{k}{(1-\eta)} \left\{ \overline{p}^{1-\eta} + \frac{1}{2\delta(2-\eta)} \left((S-\delta)^{2-\eta} - (S+\delta)^{2-\eta} \right) \right\} \end{aligned} \quad \text{if } p_* \leq S - \delta \qquad (2.17)$$

Finally, the welfare function is derived by summing expected consumer surplus and weighted expected profits:

$$W^e(p_*) = V^e(p_*) + \gamma[\pi^e(p_*) - \psi(S)] \tag{2.18}$$

$$= \begin{cases} \frac{k}{(1-\eta)}\left\{\overline{p}^{1-\eta} + \frac{\left((S-\delta)^{2-\eta}-(S+\delta)^{2-\eta}\right)}{2\delta(2-\eta)}\right\} - \gamma\psi(S) & \text{if } p_* \leq S-\delta \\ \frac{k}{1-\eta}\overline{p}^{1-\eta} + \frac{k\left(p_*^{2-\eta}-(S+\delta)^{2-\eta}\right)}{2\delta(1-\eta)(2-\eta)} & \\ -\frac{kp_*^{1-\eta}}{2\delta(1-\eta)}(p_* - S + \delta) + \gamma\frac{k(p_*-S+\delta)^2}{4\delta p_*^{\eta}} - \gamma\psi(S) & \text{if } S-\delta < p_* < S+\delta \\ \frac{k}{(1-\eta)}(\overline{p}^{1-\eta} - p_*^{1-\eta}) + \gamma\frac{k(p_*-S)}{p_*^{\eta}} - \gamma\psi(S) & \text{if } p_* \geq S+\delta \end{cases}$$

where $\psi(S) = \dfrac{\omega}{2}S^2 - \tau S + \dfrac{\tau^2}{2\omega}$.[7] For $k = 1$ and $\eta = 0$ this reduces to the inelastic case.

The next step is to substitute the solution for slackness into the welfare function and to maximise the function with respect to p_*. The optimal levels of slackness and commitment can then be derived using equations (2.16) and (2.7). The solutions apparently cannot be obtained analytically, so I examine the effect of the elasticity of demand on the optimal level of commitment numerically. I calculate the optimal levels of commitment, $\widehat{C}$, for changing values of η and γ, while holding all other parameters constant. I assume the following fixed parameter values: $\overline{p} = 50$, $\tau = 10$, $\omega = 2$, $\delta = 1$, $k = 1$. The results are shown in table 2.1.

γ / η	0	0.2	0.4	0.6	0.8	1
0	0.25	0.2941	0.3571	0.4545	0.625	1
0.5	0.1099	0.1324	0.1662	0.2226	0.3337	0.6308
1.5	0.0226	0.0278	0.0362	0.0516	0.0872	0.2094
3	0.0022	0.0027	0.0036	0.0053	0.0120	0.0509

Table 2.1: Optimal Level of Commitment, $\widehat{C}$, for varying values of η and λ

The shape of the welfare function in Figure 2.10 is the same as for the inelastic case. Welfare is constant over the first interval. It then becomes concave over the middle interval reflecting the trade-off between productive efficiency and rents for

[7] For $\eta = 1$ the welfare function takes a slightly different form. However, this does not affect my results.

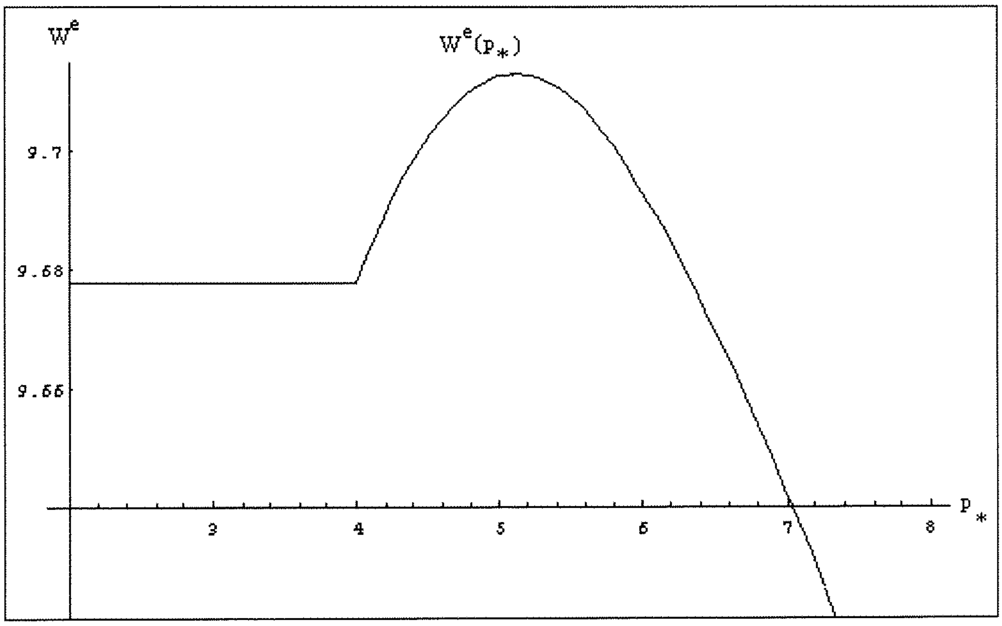

Figure 2.10: $W^e(p_*)$ for $\gamma = 1$, $\eta = 0.5$, $\overline{p} = 50$, $\tau = 10$, $\omega = 2$, $\delta = 1$

the firm. Finally, it is decreasing over the upper interval. For the given parameter values increases in elasticity, η, reduce the optimal level of commitment, $\widehat{C}$. (I have found no cases in which $\widehat{C}$ is increasing in η.) As demand becomes more elastic, the convexity of consumer surplus increases such that there are greater benefits from discretion. Increases in the weight on profits raise the optimal level of commitment. As γ increases the regulator becomes less concerned about conferring rents on the firm and therefore concentrates on maximising productive efficiency. For high levels of elasticity, such as $\eta = 5$ in Figure 2.11 full discretion is optimal.

Some caution must be taken with regard to these results with isoelastic demand. Several effects take place in response to an increase in elasticity. There is a change in $W^e_{p_*}$ (the direct loss of welfare from increases in p_*), W^e_S (the indirect gain from reduced slackness) and S_{p_*} (the sensitivity of slackness to the lower bound). Finally the demand curve ($q(p) = kp^{-\eta}$) shifts. There may some parameter values for which an increase in η raises the level of commitment.

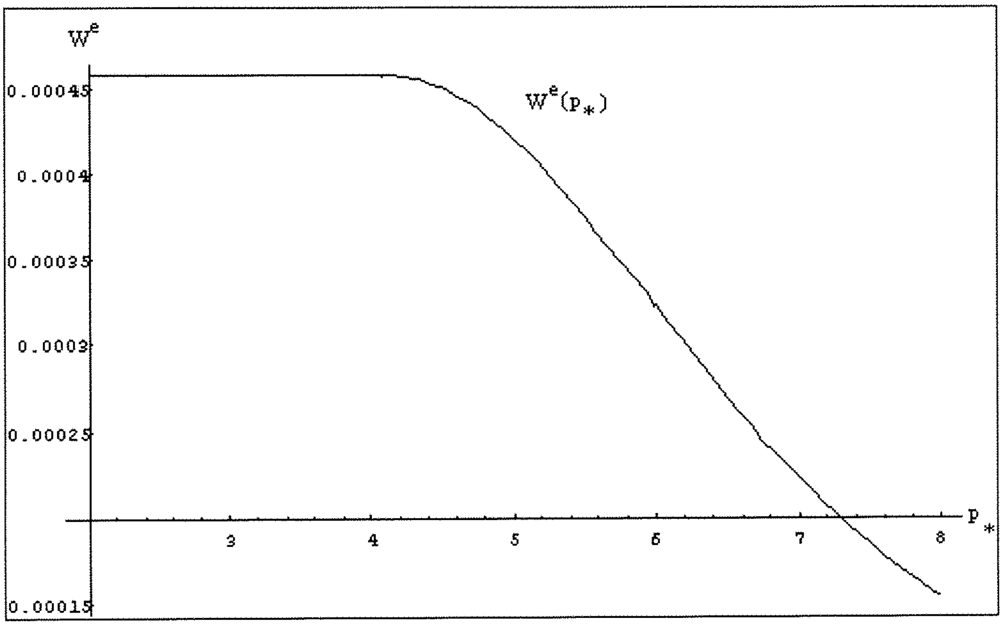

Figure 2.11: $W^e(p_*)$ for $\gamma = 1$, $\eta = 5$, $\overline{p} = 50$, $\tau = 10$, $\omega = 2$, $\delta = 1$

2.4 Final Remarks

Establishing regulatory credibility and thereby overcoming the tendency towards underinvestment is vital for a successful regulatory policy. However, this often means sacrificing the flexibility to adapt policies to a changing environment. I have been concerned with finding the optimal level of commitment to policy for the regulator of a firm with market power. This involves a trade-off between productive efficiency, allocative efficiency, and the amount of rents accruing to the firm. High levels of commitment provide strong incentives for investment, but leave large rents for the utility and reduce allocative efficiency. High levels of discretion create only weak incentives for investment, but give the regulator the opportunity to adjust prices according to realised costs. Several factors are important in determining the outcome of this relationship. These are the level of uncertainty, the elasticity of demand, the cost of investment (slackness), and how the regulator values profits. As the level of uncertainty increases there are greater benefits from being able to adjust prices in line with realised costs. The optimal level of commitment falls. An increase in the cost of investment leads to a higher level of commitment, but the level of investment declines. Increases in elasticity reduce the optimal level of commitment. As demand becomes more elastic the convexity of the consumer surplus function increases, and therefore there are greater gains from discretion. Finally, the optimal level of commitment is increasing in the weight on profits, as the regulator becomes less concerned about conferring rents on the firm.

In transitional economies such as the CEE countries, where problems of underinvestment need to be prioritised, regulatory regimes with high levels of commitment may be most suitable. High costs of investment and low levels of credibility in legal institutions mean that commitment is vital for fostering suitable levels of investment. In more developed economies, where levels of investment have been much higher and systems of contract law are better established, a more flexible regulatory regime may be required.

Chapter 3

Partial Privatisation: The Effects of Privatisation Decisions on Regulatory Incentives

3.1 Introduction

An important issue concerning the regulation and restructuring of privatised monopolies is the effect that government privatisation decisions have on future incentives to regulate the industries. In particular does the level of privatisation by the government affect its incentives for price regulation? What impact do such incentives have on levels of investment by the management of privatised companies? The privatisation of British Telecom saw the initial sale of just over fifty per cent of the firm's equity to the private sector, but the government retained a substantial stake for many years. The principal liberalisation of the industry occurred later and price regulation was initially lax but strengthened over time.[1]

The continued government ownership of equity in the privatised companies brings its interests closer in line with those of the private shareholders. As such the government may have a weaker incentive to appropriate the returns from sunk investments and higher levels of investment may take place. By contrast, if privatisation is complete, a government unable to commit to prices might choose to bring prices in line

[1] 50.2% of BT's shares were sold to the private sector in 1984. The second tranche was sold in 1991 and the final tranche in 1992. See Armstrong et al (1994).

with realised avoidable costs. Many important sunk investments may not be made.

These issues arise from the incompleteness of contracts. Given complete information and credible commitment to prices economic efficiency could be achieved whatever the level of privatisation. In practice imperfect information, and the lack of credible commitments mean that privatisation decisions are important for the regulation and performance of privatised industries.

The traditional literature on privatisation, reviewed by Vickers and Yarrow (1988), emphasises four main motives for a transfer of ownership: improving economic efficiency, improving the firm's bargaining power in wage negotiations, raising revenue to reduce government debt, and encouraging wider share ownership.

Privatisation may improve managerial incentives for efficiency. Bös and Peters (1986) argue that privatisation switches the principal's objectives from welfare maximisation to profit-maximisation and increases monitoring incentives. The decision to privatise amounts to a trade-off between allocative efficiency and productive efficiency. Public managers produce the socially optimal level of output for a given level of costs, whereas private managers maximise profits and achieve a greater level of productive efficiency. The optimal ownership structure depends on the relative size of these two effects. Laffont and Tirole (1993, ch. 17) develop a similar model where differences in efficiency between public and private firms are attributed to differences in incentive structures. Under public ownership there is suboptimal investment by managers in assets that enhance social welfare. Such investments are socially optimal, but involve an expropriation of the firm's investment from profit-making uses. Under private ownership the source of inefficiency is that the manager faces two principals. Conflicts between the regulator's and the shareholders' objectives reduce the power of managerial incentive schemes and thereby reduce productive efficiency. The optimal form of ownership trades off these effects.

Privatisation may strengthen the firm's bargaining power when negotiating with workers and thereby allow it to lower costs and improve efficiency. Haskel and Szymanski (1992,1993) consider a bargaining theory of privatisation where costs are modelled explicitly as wages. The prevailing wages are the outcome of a bargaining process between the firm and its workers. Public sector firms have wider social objectives than firms in the private sector and also face a soft budget constraint. Privatisation therefore enables firms to lower costs and improve efficiency.

Privatisation can be a useful means of raising revenue if there are significant distortionary effects from taxation. Ballard, Shoven and Whalley (1985) estimate the shadow price of public funds in the U.S. to be 0.3. One would expect a much higher shadow price in many transition economies where tax collection is less efficient. There are equally important political reasons for raising extra capital. Short-term revenues from privatisation sales are valuable because they enable the government to reduce the budget deficit and fulfil some of their manifesto promises, thereby improving their chances of re-election. UK privatisation revenues have usually been deducted from gross expenditure figures rather than treated as a source of revenue. Heald (1984) states

> The 'special sale of assets' programme thus performs a dual function: it provides tangible evidence that the Government is fulfilling its promise to roll back the state; and it makes any given planning target easier to achieve.

The aim of achieving wider share ownership in the UK has only been moderately successful. Mayer and Meadowcroft (1985) note that early privatisations such as Amersham International and British Aerospace showed little evidence of increasing the diversity of share ownership. There was little incentive for small private shareholders to hold onto their shares for more than a few months. By contrast, the British Telecom and British Gas privatisations have greatly increased the number of share-owners, but their shares are spread very thinly.[2]

[2] See Vickers and Yarrow (1988) for a discussion about the objectives of wider share ownership.

Assuming that privatisation is an effective mechanism for raising government revenues and improving economic efficiency, the natural extension for theory is to explain how firms should best be privatised and what effects privatisation has on subsequent regulation of these industries. These issues are the focus of this chapter.

The recent literature on privatisation in transition economies, such as the economies of Central and Eastern Europe (CEE), has focussed on the appropriate and feasible speed of privatisation. Coricelli and Milesi-Ferretti (1993) show that rapid privatisation of firms may lead to problems of excess liquidation. Participants in a worker-controlled firm may decapitalise the firm in order to maximise their utility. Dewatripont and Roland (1993) show that more gradual privatisation and restructuring enhances feasibility. It allows for policy reversal if restructuring turns out to be unsuccessful. A gradual process of privatisation may equally be pursued to maximise privatisation revenues. A staged privatisation programme may enhance regulatory credibility and increase privatisation revenues. Armstrong and Vickers (1996) suggest that the desire to earn future revenues from privatisation acts as a deterrent to government opportunism. Provided that there are further privatisations on the agenda, the government will be deterred from reneging on its announced policies. Salant and Woroch (1991) develop the related idea that firms should gradually build up their capacity rather than immediately investing in the efficient capital stock. If a firm immediately invests in the efficient level of capacity the regulator will set price equal to marginal cost and the firm will make a loss equal to the level of its sunk costs. Anticipating this behaviour the firm will choose not to invest. A gradual build up of capacity, however, can be sustained. Suppose that the regulator's price is set to cover the cost of the firm's investment in the previous period, and will fall asymptotically to zero over time. If the firm believes that the regulator's pricing policy is credible it will be in its interest to steadily build up capacity.

The literature on staged-financing of large capital investments and initial public offerings (IPOs) suggests further reasons why it may be optimal to pursue gradual privatisation. Mello and Parsons (1998) show that an initial sale of equity to small investors provides valuable information that can be used to negotiate the price at which the controlling shares are sold to active investors. This increases the total revenue for the seller. Zingales (1995) argues that if the seller has stronger bargaining power against passive rather than active investors it is optimal for her to sell a portion of the shares to passive investors prior to selling the controlling block.

More attention, however, needs to be paid to the relationship between privatisation decisions and the subsequent regulation of privatised industries. The structure of privatisation has important consequences for future regulatory incentives. Nomer et al (1997) use a reputation model to examine the sale and regulation of a sequence of firms when the monitoring of regulatory compliance is costly. The government is concerned with raising revenues as well as with increasing efficiency. The government has an incentive to monitor the firm more loosely than in a standard regulation model as this allows for higher profits and therefore greater privatisation revenues.

Wider share-ownership may place important political constraints on the government expropriating rents and lead to higher levels of sunk investment. Vickers (1991) shows that if the public has a large proportion of the shares in the utilities they may oppose renationalisation or a tightening of price controls. In a similar vein Bös and Harms (1997) use a signalling model to show that it is optimal to privatise a firm to a large number of small shareholders. In their model this dilutes the shareholders' monitoring incentives in the final stage of the game, allowing the manager to gain a greater share of the firm's profits, and therefore gives the manager a stronger incentive to undertake profitable restructuring.

In this chapter I consider the possibility of partial privatisation of a firm under imperfect information and find the optimal level of privatisation. In so doing I examine the effects of privatisation decisions on regulatory incentives and managerial incentives for cost-reducing effort. I assume that there is a monopolistic firm facing known demand but having unknown costs. The government chooses to sell a proportion of the equity in the firm to an owner-manager to raise revenues. It then regulates the firm's prices but does not interfere in its management. The government chooses the level of privatisation strategically to manipulate its own future incentives for price regulation and therefore to influence the manager's effort choice. Partial privatisation is effectively a form of commitment by the government to higher regulated prices and may therefore induce higher levels of investment.

The optimal level of privatisation involves a trade-off between giving the manager a greater share of the firm's profits and increasing the risk of expropriation by the government. As more equity is sold to the owner-manager of a privatised monopoly she receives a greater proportion of the firm's profits. This improves her incentives for productive efficiency and raises the share price. On the other hand it increases the risk of expropriation for the manager which depresses the share price. Complete privatisation reduces the credibility of regulatory policies and the incentives for making sunk investments.

Bös (1991) considers an alternative view of partial privatisation. The government retains a share of the firm in order to maintain influence over its decision-making. It regulates the firm internally by sending government representatives to its board of directors rather than regulating it externally through price regulation. The board is therefore made up of a combination of private shareholders who wish to maximise profits and government representatives who wish to maximise social welfare. Decisions depend on the outcome of a bargaining process between the two sets of representatives. Higher levels of privatisation raise the private owners' bargaining power and lead to improved productive efficiency but reduced allocative efficiency.

In section 3.2 I develop a model where the government chooses the level of privatisation, the manager chooses the level of cost-reducing effort and the government regulates the firm's prices. I determine the welfare-maximising regulatory scheme, the utility-maximising choice of effort for the manager and the optimal level of privatisation. In section 3.3 I examine possible extensions to my model. A summary of my results and final remarks are given in section 3.4.

3.2 A Model of Partial Privatisation

Consider a monopolistic firm that produces a single good. The firm faces demand, $q(p)$, where $q'(p) < 0$. The marginal operating cost is constant and equal to c. I assume that the firm is initially under public ownership and has a high marginal cost, c_H, because of problems of bureaucracy and weak monitoring in the public sector.

The government chooses to sell a proportion, s, of the equity in the firm to an owner-manager. The manager's role is to undertake some level of effort, $e \geq 0$, in order to reduce future production costs. For example, the manager can try to streamline the production process, find new suppliers, layoff surplus staff etc. Under partial privatisation the high- and low-cost states, c_H and c_L, occur with probabilities $1 - e$ and e respectively. The cost of effort for the manager is given by the function $\psi(e) = \frac{d}{2}e^2$. I assume that d is sufficiently large to guarantee an interior solution for effort. There are no additional fixed costs.

I am only concerned here with the effects of the level of privatisation on future regulation, effort choices, and privatisation revenues. Therefore the only incentive scheme for the manager is a share of the firm's profits. I am not concerned with fine-tuning incentive schemes.

After privatisation the government regulates the firm's prices. The marginal cost, c, is observable but not verifiable for the government and the level of effort, e, cannot be observed. The government therefore cannot set a contract which conditions the regulated price on the future level of costs or the manager's effort. It sets the price having observed realised costs.

The time structure of the model is summarised in Figure 3.1.

In period 1, the government chooses to sell a proportion, s, of the equity in the firm to an owner-manager. I assume that the government makes a take-it-or-leave-it offer to sell the equity at price, α. In period 2 the manager makes her effort decision,

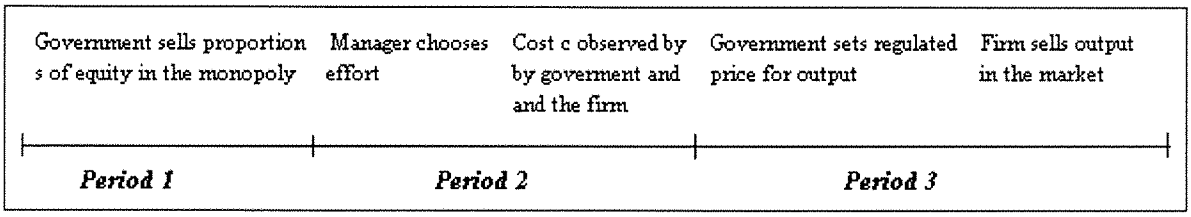

Figure 3.1: Move Order

based on her expectation of future profits, and both the government and the owner-manager observe the marginal operating cost, c. This is simpler than the case where the firm has private information as to the true value of c, as the low-cost type is unable to gain rents by mimicking the high cost-type. In period 3 the government sets the regulated price, p, at which the firm may sell its product. The firm then produces and sells its output in the market.

The UK government has typically announced that it would not interfere in the management of the firm once the privatisation process had begun. Its involvement would be restricted to a well-defined regulatory regime. For this reason, in this section, I assume that the owner-manager has the control rights over the firm once partial privatisation has taken place.

All parties are risk-neutral and there is no discounting. Payoffs are realised at the end of period and are given by

$$U(p) = s\Pi(p) - \frac{d}{2}e^2 - \alpha$$

for the manager and

$$\begin{aligned} W(p) &= U(p) + V(p) + (1+\lambda)[(1-s)\Pi(p) + \alpha] \\ &= V(p) + (1 + \lambda(1-s))\Pi(p) + \lambda\alpha - \frac{d}{2}e^2 \end{aligned} \tag{3.1}$$

for the government. The manager's objective function is equal to the dividends from her shares minus the cost of effort and the price paid for the shares. The government's objective function is the sum of the manager's utility, consumer surplus, dividends from retained equity and privatisation revenues, weighted by the shadow price of public funds.[3] Consumer surplus is $V(p)$ at price p. The proportion of equity sold to the owner-manager is s, and the firm's profits are $\Pi(p) = q(p)(p-c)$. The shadow price of public funds is λ. I assume that $\lambda \geq 0$. This reflects the distortionary effects of government taxes levied to raise extra revenue. This may give the government an incentive to raise revenues through any less distortionary mechanism such as privatisation.

Finally I assume that the government is unable to pre-commit to the pricing policy it will choose in the final stage of the game. This assumption is crucial. If the government can commit to a price $\bar{p}$ before privatisation takes place it will be indifferent to the actual level of privatisation it undertakes.

The analysis proceeds as follows:

- I solve the game by backwards induction, firstly determining the regulated price in the final stage of the game.
- I find the utility-maximising level of effort for the owner-manager.
- Finally, I derive the government's expected welfare for a given level of s and find the optimal level of privatisation.

3.2.1 Price Regulation

The government chooses the regulated price to maximise the expected value of its objective function, subject to meeting the firm's break-even constraint. It takes the level of privatisation and the firm's realised cost as given. The government must trade off the benefits of lower prices and increased consumer surplus against the costs of

[3] The government's objective function can easily be rewritten in terms of quantities as in Clemenz (1991). I then have $W(q) = U(q) - cq + \lambda(1-s)(p(q)-c)q + \lambda\alpha$ where $U'(q) = p(q)$. There may also be a distinction between the government's objective function and the social welfare function. If the shadow price is based on a political motive it should not be included in the social welfare function, which could be represented by the unweighted sum of consumer surplus and profits. $SW(p) = V(p) + \Pi(p)$. The government's objective function is then, in effect, distorted by political pressures.

reduced dividends and therefore reduced revenues.

$$\max_{p} W(p) = V(p) + (1 + \lambda(1-s))\Pi(p) + \lambda\alpha - \frac{d}{2}e^2 \text{ s.t. } (p-c) \geq 0$$

$$\frac{dW(p)}{dp} = \lambda(1-s)q(p) + (1+\lambda(1-s))q'(p)(p-c) = 0$$

The welfare-maximising regulated price satisfies the following condition.

$$\frac{p-c}{p} = \frac{\lambda(1-s)}{(1+\lambda(1-s))\eta} = \frac{\widetilde{\lambda}}{(1+\widetilde{\lambda})\eta}$$

where $\eta = \frac{p'q}{q}$ is the price elasticity of demand and $\widetilde{\lambda} = \lambda(1-s)$ is the adjusted-shadow price. This is simply a variant of Ramsey Pricing taking into account the level of privatisation by the government in the first stage of the game and the shadow price of public funds. If there are no distortionary effects of government taxation ($\lambda = 0$) or privatisation is complete ($s = 1$) marginal cost pricing is optimal ($p = c$). The government is simply interested in maximising allocative efficiency and fully expropriates any returns from cost-reducing effort. For a positive shadow price and partial privatisation there is positive mark-up over costs.

For the case of a linear demand function, $q(p) = \gamma - \tau p$, regulated profits are:

$$\Pi(c,s) = \frac{\lambda(1-s)(1+\lambda(1-s))(\gamma - \tau c)^2}{\tau(1+2\lambda(1-s))^2}.$$

Profits are decreasing in the marginal cost, c. As costs increase the mark-up of price over cost falls and the firm earns lower profits. Profits are decreasing in the level of privatisation s.[4] As the level of privatisation increases the government becomes less interested in maintaining the profitability of the firm and more concerned with raising consumer surplus. It sets a lower mark-up over costs. Profits are increasing in the shadow price of public funds.[5] As the government becomes more concerned

[4] $\frac{d\Pi(c,s)}{ds} = \frac{-\lambda(\gamma - \tau c)^2}{(1+2\lambda(1-s))^3\tau} < 0$

[5] $\frac{d\Pi(c,s)}{d\lambda} = \frac{(1-s)(\gamma - \tau c)^2}{(1+2\lambda(1-s))^3\tau} \geq 0$

with the political benefits of raising revenues to lower the budget deficit it sets looser price regulation and therefore both the firm's profits and the government's dividends increase.

For linear demand consumer surplus is equal to

$$V(c,s) = \frac{(1+\lambda(1-s))^2(\gamma-\tau c)^2}{2\tau(1+2\lambda(1-s))^2}.$$

Consumer surplus is decreasing in the marginal cost, c. As costs increase the regulated price increases and consumer surplus falls. Consumer surplus is increasing in the level of privatisation.[6] As the level of privatisation increases the government becomes more interested in reducing prices for consumers and less concerned with profits. Consumer surplus is decreasing in the shadow price of public funds.[7] As the government becomes more concerned with raising government revenues it sets a higher regulated price.

3.2.2 The Effort Decision of the Owner-Manager

The owner-manager chooses her effort level to maximise her expected utility. She trades off the benefits of lower expected marginal costs and therefore a share of higher expected profits against the increasing costs of effort.

$$\begin{aligned}\max_{0\le e\le 1} U(\cdot) &= se\Pi(c_L,s) + s(1-e)\Pi(c_H,s) - \frac{d}{2}e^2 - \alpha \\ &= s\Pi(c_H,s) + \Delta se - \frac{d}{2}e^2 - \alpha\end{aligned}$$

where $\Delta = \Pi(c_L,s) - \Pi(c_H,s)$. The utility-maximising level of effort is

$$e(\Delta) = \frac{s}{d}\Delta.$$

6 $\frac{dV(c,s)}{ds} = \frac{\lambda(1+\lambda(1-s))(\gamma-\tau c)^2}{(1+2\lambda(1-s))^3\tau} \geq 0$

7 $\frac{dV(c,s)}{d\lambda} = -\frac{(1-s)(1+\lambda(1-s))(\gamma-\tau c)^2}{(1+2\lambda(1-s))^3\tau} \leq 0$

Clearly effort is increasing in the difference in profits between states.

For the case of a linear demand function, $q(p) = \gamma - \tau p$, the utility maximising level of effort is

$$\widehat{e} = \frac{s\lambda(1-s)(1+\lambda(1-s))(c_H - c_L)(2\gamma - \tau(c_H + c_L))}{d(1+2\lambda(1-s))^2} \leq e^*.$$

(I assume $2\gamma - \tau(c_H + c_L) > 0$.) The government's inability to commit to prices causes a loss of productive efficiency. Effort is less than or equal to the efficient level e^*.[8] The effort function is concave in the level of privatisation, s, as shown in Figure 3.2 ($\frac{de}{ds} > 0$ at $s = 0$ and $\frac{d^2e}{ds^2} \leq 0$.[9])

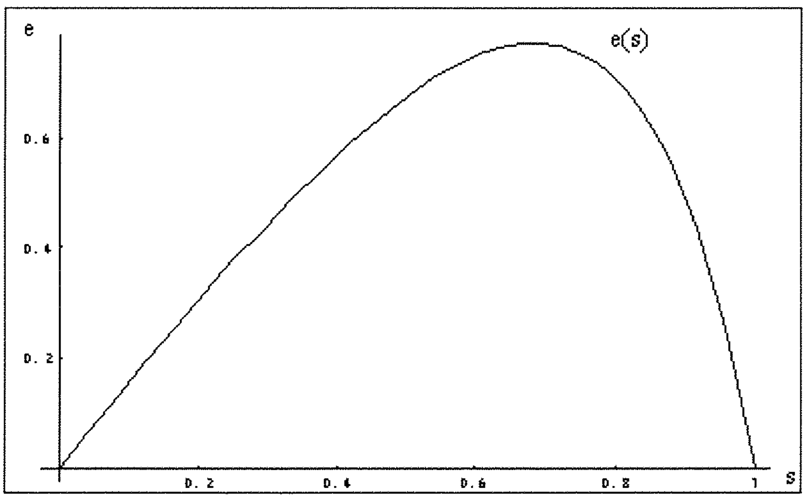

Figure 3.2: Solution for Effort

As s increases there are two opposing effects: firstly, the owner-manager receives a greater share of the firm's profits, and secondly thedifference in the firm's profits

[8] The efficient level of effort is $e^* = \dfrac{(1+\lambda)(c_H - c_L)(2\gamma - \tau(c_H + c_L))}{2d(1+2\lambda)}$.

[9]

$$\left.\frac{de}{ds}\right|_{s=0} = \frac{(1+\lambda)(c_H - c_L)(2\gamma - \tau(c_H + c_L))}{d(1+2\lambda)^2} > 0,$$

$$\frac{d^2e}{ds^2} = -\frac{2\lambda(1+2\lambda(2+s))(c_H - c_L)(2\gamma - \tau(c_H + c_L))}{d(1+2\lambda(1-s))^4} \leq 0$$

between states is reduced. Initially the first effect dominates and the owner-manager receives more powerful effort incentives. The utility-maximising level of effort increases. For high levels of privatisation, however, the second effect dominates and the level of effort is decreasing in s.

As the level of privatisation approaches zero ($s \to 0$) the manager's effort tends towards zero. If the manager only owns a small proportion of the firm's equity she only receives a small share of the profits and the returns from her cost-reducing investment will be low.

Under complete privatisation ($s = 1$) the forward-looking manager undertakes no effort. The government has no equity in the firm so it will simply be interested in maximising consumer surplus. It will set price equal to realised costs and the manager will receive no return from her cost-reducing effort. For intermediate levels of s she undertakes positive effort levels and there is an improvement in productive efficiency.

Given a zero shadow price of public funds ($\lambda = 0$) the government fully expropriates the returns from any cost-reducing effort. Hence the forward-looking manager undertakes no effort.

The utility-maximising level of effort is increasing in the shadow price of public funds.[10] As the distortionary effect of taxation or political benefits of raising funds increase the difference in profits between states grows. The manager has a greater incentive to invest and therefore chooses a higher level of effort.

Finally, the level of effort is increasing in the difference in marginal costs between states and decreasing in the cost of effort.[11] As the difference in marginal costs between states grows the reward for effort rises. As the cost of effort rises the utility-maximising level of effort falls.

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[10] $\dfrac{de}{d\lambda} = \dfrac{s(1-s)(c_H - c_L)(2\gamma - \tau(c_H + c_L))}{d(1 + 2\lambda(1-s))^3} \geq 0.$

[11] $\dfrac{de}{dc_H} = \dfrac{2\lambda s(1-s)(1 + \lambda(-1s))(\gamma - \tau c_H)}{d(1 + 2\lambda(1-s))^2} \geq 0.$

3.2.3 Government's Privatisation Choice

The government chooses the amount of equity that is sold in the first-period of the game and the price at which it is sold, taking into account the effects on the owner-manager's effort decision, its own incentives for price regulation, and its desire to raise revenue from privatisation. As the government is unable to pre-commit to prices selling more equity tightens the regulation in the final stage of the game and thereby reduces effort incentives. Retaining more equity softens the regulation in the final stage of the game and increases the power of effort incentives. Partial privatisation is, in effect, a form of commitment by the government to higher prices and can therefore induce higher levels of sunk investment.

I have assumed that the government has all of the bargaining power so that it can fully extract rents from the owner-manager. The owner-manager's participation constraint is therefore binding:

$$E_c U(c,s) = E_c[s\Pi(c,s) - \psi(e) - \alpha] = 0$$

Given this assumption the expected value of the government's objective function (equation 3.1) may be written as follows:

$$E_c W(c,s) = E_c V(c,s) + (1+\lambda) E_c[\Pi(c,s) - \psi(e)]$$

The government's objective function is a weighted sum of consumer surplus and profits minus the cost of effort.

The expected level of consumer surplus is

$$E_c V(c,s) = V(c_H,s) + \frac{s}{d}[\Pi(c_L,s) - \Pi(c_H,s)](V(c_L,s) - V(c_H,s)). \tag{3.2}$$

Expected profits minus the cost of effort are:

$$E_c[\Pi(c,s) - \psi(e)] = \Pi(c_H,s) + \frac{s(2-s)}{2d}[\Pi(c_L,s) - \Pi(c_H,s)]^2. \tag{3.3}$$

The government's expected welfare is derived by substituting equations (3.2) and (3.3) into the government's objective function.

$$\begin{aligned} E_cW(c,s) &= V(c_H,s) + \frac{s}{d}[\Pi(c_L,s) - \Pi(c_H,s)](V(c_L,s) - V(c_H,s)) \\ &\quad +(1+\lambda)\left\{\Pi(c_H,s) + \frac{s(2-s)}{2d}[\Pi(c_L,s) - \Pi(c_H,s)]^2\right\}. \end{aligned}$$

For linear demand, $q(p) = \gamma - \tau p$, the objective function can be rewritten in the following form:

$$\begin{aligned} &E_cW(c,s) = \frac{(1+\lambda(1-s))(1+\lambda(1-s)(3+2\lambda))(\gamma-\tau c_H)^2}{2\tau(1+2\lambda(1-s))^2} \\ &+\left\{\frac{s\lambda(1-s)(1+\lambda(1-s))^2(1+\lambda(1-s)(1+(2-s)(1+\lambda)))}{2d(1+2\lambda(1-s))^4}\right\} \\ &(c_H - c_L)^2(2\gamma - \tau(c_H+c_L))^2. \end{aligned} \tag{3.4}$$

The objective function has the shape shown in Figure 3.3 for the following parameter values: $\gamma = 15, \tau = 2$, $\lambda = 1, d = 10$, $c_H = 4$, and $c_L = 2$.

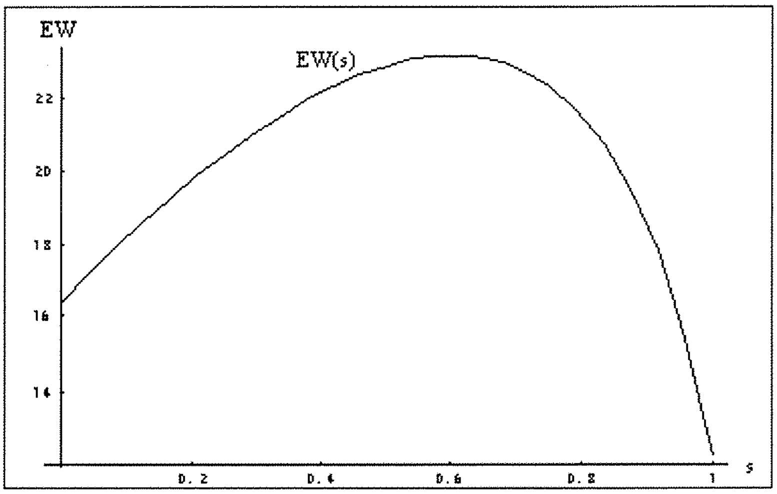

Figure 3.3: Solution for Welfare

The optimal level of privatisation is found by differentiating the expected welfare function with respect to s and setting the first-order-condition equal to zero. This solution apparently cannot be obtained analytically, so I use comparative statics and numerical simulations to examine the effects of changes in the parameter values on the optimal level of privatisation, $\widehat{s}$.

If there are no distortionary effects from the government levying taxes to raise revenue or no political benefits from the short-term reduction of budget deficits (i.e. the shadow price of public funds is equal to zero) the government will be indifferent as to the level of privatisation it undertakes. The government simply maximises the unweighted sum of consumer surplus and profits and sets price equal to marginal operating costs in the final stage of the game. There is allocative efficiency, but the firm earns zero profits. Anticipating this, the forward-looking manager undertakes no effort. The value of the firm's equity is therefore zero and the government's welfare is simply consumer surplus with price equal to marginal cost in the high-cost state. This is independent of s.

$$W = \frac{(\gamma - \tau c_H)^2}{2\tau} \text{ for } \lambda = 0 \text{ or } s = 1.$$

Under complete privatisation the government sets the price equal to marginal cost. The forward looking manager undertakes no effort and the firm makes no profits. Social welfare is again equal to consumer surplus with price equal to marginal cost in the high-cost state.

If taxation has distortionary effects or the government derives political benefits from its revenues (i.e. there is a positive shadow price) the government will choose a limited level of privatisation.

$$\begin{aligned}
\left.\frac{dE_cW}{ds}\right|_{s=0} &= \frac{(c_H - c_L)^2\lambda(1+\lambda)^3(2\gamma - \tau(c_H + c_L))^2}{2d(1+2\lambda)^3} \geq 0 \\
\left.\frac{dE_cW}{ds}\right|_{s=1} &= -\frac{\lambda^2(\gamma - \tau c_H)^2}{\tau} - \frac{(c_H - c_L)^2\lambda(2\gamma - \tau(c_H + c_L))^2}{2d} \leq 0
\end{aligned}$$

Under full public ownership ($s = 0$) the marginal benefit of selling equity is non-negative. Giving the owner-manager a share in the profits of the firm gives her positive effort incentives and thereby improves productive efficiency and expected welfare.

Similarly under complete privatisation ($s = 1$) the marginal benefit of retaining some equity is non-negative. Again this gives the owner-manager a share of positive profits, and thereby increases productive efficiency and welfare.

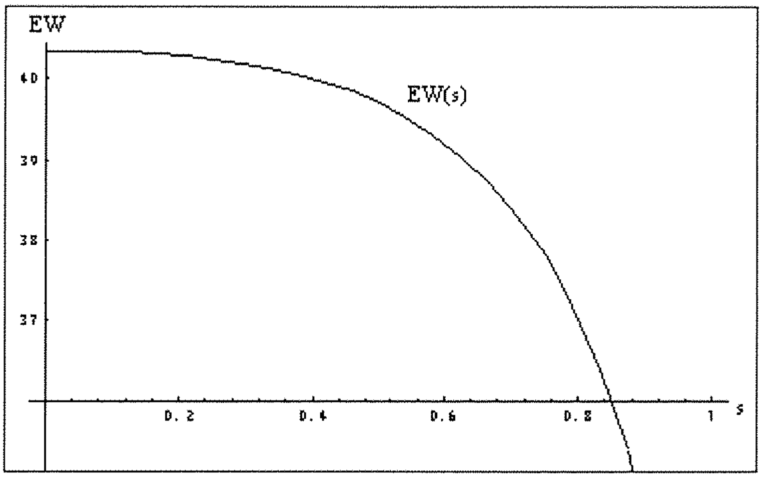

Figure 3.4: Graph of Welfare for $\gamma = 15$, $\tau = 2$, $\lambda = 1, c_H = c_L = 2$

For a high cost of effort ($d = \infty$) or with no difference in marginal costs between states ($c_H = c_L$) full public ownership will always be preferable, as illustrated in Figure 3.4. Given a positive shadow price the government's benefits from increased profits and revenues outweigh the costs of higher prices and reduced consumer surplus.

$$\frac{dE_cW}{ds} = \frac{-\lambda^2 s(\gamma - \tau c_H)^2}{(1 + 2\lambda(1 - s))^3 \tau} < 0$$

$$\Rightarrow \widehat{s} = 0$$

What are the effects of changes in the shadow price of public funds, the cost of effort and the difference in marginal costs between states on the optimal level of privatisation, $\widehat{s}$? Given the complex form of the first-order-condition, I have carried out simulations of the optimal level of privatisation, $\widehat{s}$, for varying values of c_H, λ, and d, holding the other parameter values constant. I assume the following fixed parameter values: $\gamma = 15$, $\tau = 2$, and $c_L = 2$.[12]

[12]Clearly, the choice of fixed parameter values is arbitrary. They simply satisfy the conditions for an interior solution. However, similar results carry through for a wide range of values.

λ / c_H	0	0.5	1	2	3	4	5
2	Indet	0	0	0	0	0	0
3	Indet	0.3935	0.4028	0.4496	0.4918	0.5262	0.5544
4	Indet	0.5433	0.5651	0.6032	0.6342	0.6590	0.6793
5	Indet	0.5860	0.6199	0.6593	0.6807	0.7080	0.7252
6	Indet	0.6007	0.6405	0.6818	0.7082	0.7281	0.7441
7	Indet	0.6057	0.6478	0.6901	0.7161	0.7356	0.7512

Table 3.1: Optimal level of privatisation for varying c_H and λ, given $d = 20$

λ / d	0	0.5	1	2	3	4	5
10	Indet	0.5722	0.6015	0.6399	0.6684	0.6909	0.7092
15	Indet	0.5572	0.5823	0.6203	0.6738	0.6738	0.6932
20	Indet	0.5433	0.5651	0.6032	0.6590	0.6590	0.6793
25	Indet	0.5303	0.5496	0.5880	0.6459	0.6459	0.6670
30	Indet	0.5182	0.5354	0.5473	0.6341	06341	0.6560

Table 3.2: Optimal level of privatisation for varying d and λ, given $c_H = 4$

For the given parameter values increases in the marginal cost in the high-cost state raise the optimal level of privatisation, $\widehat{s}$. As the difference in marginal costs between states grows the marginal benefit of selling additional shares and strengthening managerial incentives increases. The government therefore sells more equity to the owner-manager, giving her a greater share of the firm's profits.

For a wide range of parameter values an increase in the shadow price of public funds, λ, raises the optimal level of privatisation. The government becomes relatively more concerned with improving productive efficiency and raising privatisation revenues than with increasing consumer surplus. The government thus expropriates less of the returns from cost-reducing effort in the final stage of the game and chooses to privatise more of the firm's equity. For a very high shadow price of public funds the optimal level of privatisation approaches complete privatisation, as shown in Figure 3.5 (As $\lambda \to \infty$ $\widehat{s} \to 1$).

As shown in Table 3.2, an increase in the cost of effort reduces the optimal level of privatisation, $\widehat{s}$. As the cost of effort increases, the benefits of increased privatisation

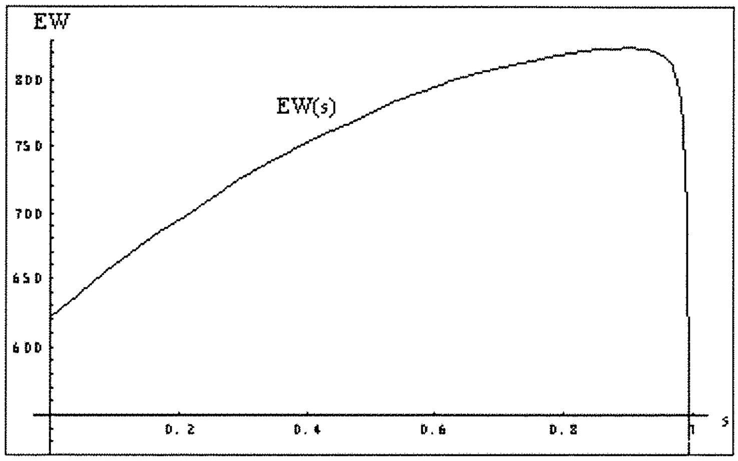

Figure 3.5: Graph of Welfare for $\gamma = 15$, $\tau = 2$, $\lambda = 50$, $d = 20$, $c_H = 4$, $c_L = 2$

in terms of productive efficiency decline relative to the benefits of allocative efficiency. The government chooses a lower level of privatisation.

3.3 Further Analysis

3.3.1 A Multi-Period Model

A natural extension of my model is to examine the effects of including more periods. In particular will the government choose to sell some of its remaining equity in the monopoly firm in future periods? In the case where the shadow price is constant and the game is repeated a finite number of times the optimal solution remains the same. The government chooses to sell a proportion of its equity in the first period and thereafter sells nothing. The same regulated price is set in each period.[13]

However, the shadow price, λ_i, may be declining before reaching some fixed level $\bar{\lambda}$. For example in transition economies the distortions from levying taxes are likely to be much greater during the early stages of restructuring than once the majority of reforms have taken place. Privatisation is an important means of raising revenue at the beginning of reforms but is much less significant later on. If the government is unable to borrow against future profits or if such borrowing comes at a high cost a de-

[13]This holds under the assumption that effort depreciates fully each period.

clining shadow price creates an important distinction between privatisation revenues and the dividends from retained equity. Privatisation sales allow the government to obtain the discounted sum of future profits upfront, when they are associated with a higher shadow price. They alleviate the government's current budgetary problems. Dividends from retained shares are acquired over time and are thus associated with a declining shadow price. Some of the profits are obtained when the government's budgetary problems have eased. The government's welfare is improved by receiving a given level of profits as privatisation revenues rather than as dividends from retained shares. This effect increases the marginal benefit of selling equity in the first period and to raises the optimal level of privatisation.

Consider a two-period version of my model. The government chooses to privatise a proportion s_1 of firm's equity to an owner-manager in period one. The manager then makes her effort choice, e_1, and the government sets the regulated price, p_1. This sequence of moves is repeated in period two. The government's first period objective function is

$$\begin{aligned} W &= V(p_1) + (1+\lambda_1)[\Pi(p_1) - \frac{d}{2}e_1^2] \\ &\quad +\delta V(p_2) + \delta(1+\lambda_2)[\Pi(p_2) - \frac{d}{2}e_2^2] \\ &\quad +\delta(\lambda_1 - \lambda_2)s_1\Pi(p_2). \end{aligned} \tag{3.5}$$

where δ is the discount factor, p_i is the price in period i, e_i is the manager's effort and λ_i is the shadow price. The final term on the right-hand side of equation (3.5) is the benefit of obtaining the second-period profits as privatisation revenues rather than as dividends from retained shares. (Note that if the shadow price is constant, $\lambda_1 = \lambda_2$ this term disappears.)

The solution to the two period model is found using backwards induction, firstly deriving the utility-maximising choices for the government and the manager in period 2, and then determining their utility-maximising choices for the first period. The solution apparently cannot be found analytically, so I have carried out simulations to find the optimal level of privatisation in each period. I assume the following constant parameter values: $\gamma = 15$, $\tau = 2$, $\lambda_1 = 2$, $\lambda_2 = 1$, $c_H = 4$, $c_L = 2$, $\delta = 0.9$, and $d = 20$. I find that the government will only sell a further tranche of shares in the second period if the proportion of shares already sold is less than 0.5084. As the government chooses to sell 0.6342 of its equity in the first period it sells nothing in period 2. The government sells more equity in the first period than in the single period model in order to obtain profits upfront when they are more valuable.

In Appendix A I consider the gradual privatisation of a publicly owned firm to passive investors. The firm's prices are regulated by the government. The privatisation and regulation process is modelled as an infinitely repeated stage game. At the beginning of each stage the government has the option of selling a proportion, s_i, of the remaining equity in the firm to private investors. It then sets a regulated price, p_i, which holds for the remainder of the period. Profits are distributed to shareholders (including the government) in the form of dividends. The shadow price of public funds, λ_i, is initially high before falling to a lower level and remaining constant. The conclusions are similar to those for the two-period model. The government sells shares when the shadow price is high to obtain future profits as privatisation revenues. However, once the shadow price has fallen the government makes no further sales.

3.3.2 Transfer of Control

The process of privatisation may involve a transfer of "control rights" or effective control from the government to private shareholders. Consider the following scenario: if the government holds more than fifty per cent of the equity it is the majority shareholder and manages the firm itself. I assume that there is a high marginal cost, c_H, with probability one. The government's expected welfare is

$$W^{GC}(s) = \frac{(1+\lambda(1-s))(1+\lambda(1-s)(3+2\lambda))(\gamma - \tau c_H)^2}{2\tau(1+2\lambda(1-s))^2} \text{ for } s < 0.5.$$

If the government sells over fifty per cent of the firm's equity to the owner-manager there is a transfer of control. The owner-manager now controls the firm and undertakes a positive level of effort as set out in section 3.2.2. The government's welfare is given by equation (3.4). There is a discontinuity in the government's welfare function at the point where control is transferred ($s = 0.5$). This is caused by a discrete jump in the effort function. There are four possible outcomes from this discontinuity.

Firstly, the government privatises a greater amount than would have been optimal without the possibility of government control. It privatises exactly fifty per cent of the shares in order to transfer control to the owner-manager and induce a positive level of effort. Any further sales reduce effort incentives, lower the regulated price and lower welfare, as shown in Figure 3.6.

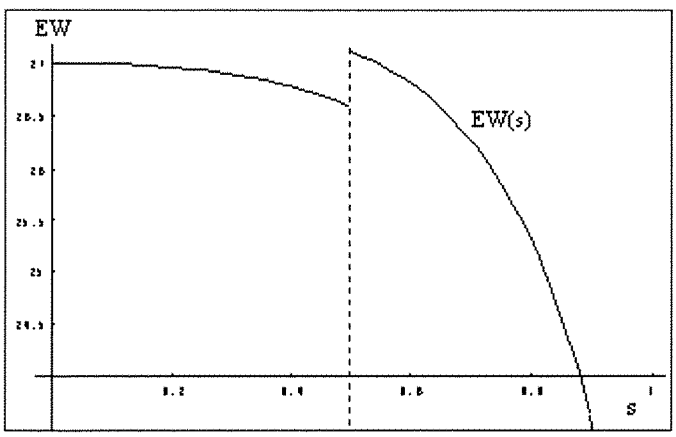

Figure 3.6: Graph of Welfare: Threshold increases level of privatisation.

In the second case the optimal level of privatisation is unaffected by the possibility of government control. (See Figure 3.7.) Since welfare in the original model was maximised for a sale of equity greater than fifty per cent, the introduction of a transfer of control has no effect on the optimal level of privatisation.

In the third case, shown in Figure 3.8, the government chooses to maintain full public ownership ($s = 0$) rather than to sell a small proportion of the equity in the firm. The removal of effort incentives for sales of equity less than fifty per cent means

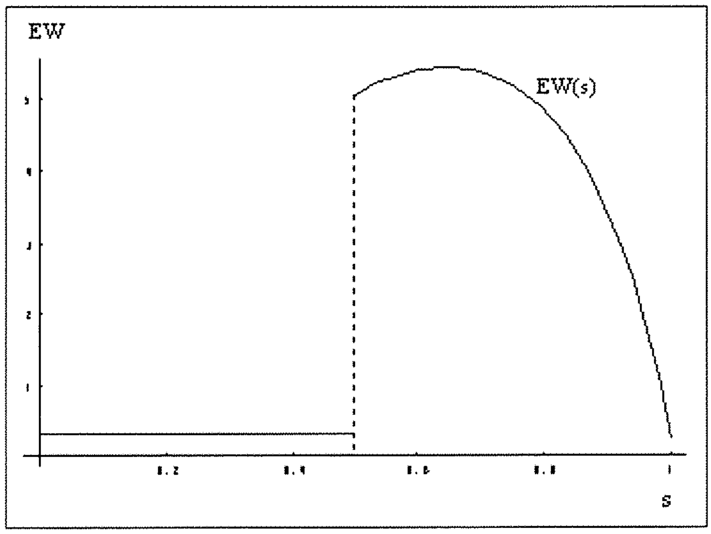

Figure 3.7: Graph of Welfare: Threshold has no effect.

that full public ownership is chosen rather than a small proportion of the shares being sold.

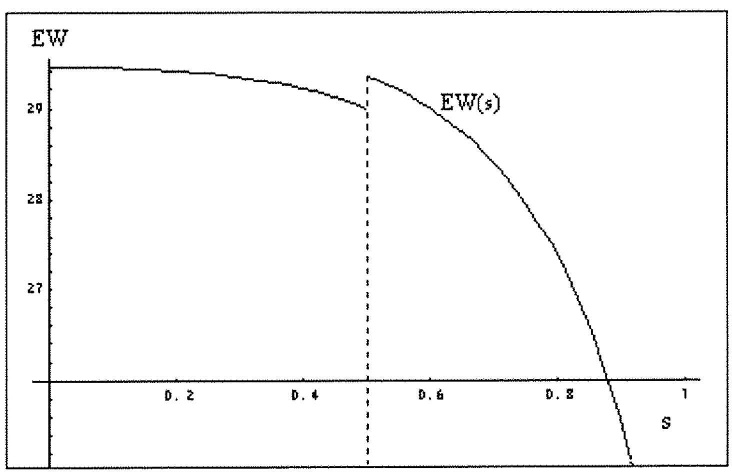

Figure 3.8: Graph of Welfare: Threshold induces full public ownership.

Finally, where full public ownership ($s = 0$) was optimal in the original model it remains optimal in the extended model. The removal of effort incentives for sales of less than fifty per cent of the firm's equity can only lower welfare over this range. (See Figure 3.9.)

For a low cost of effort, a high difference in costs between states, or a high shadow

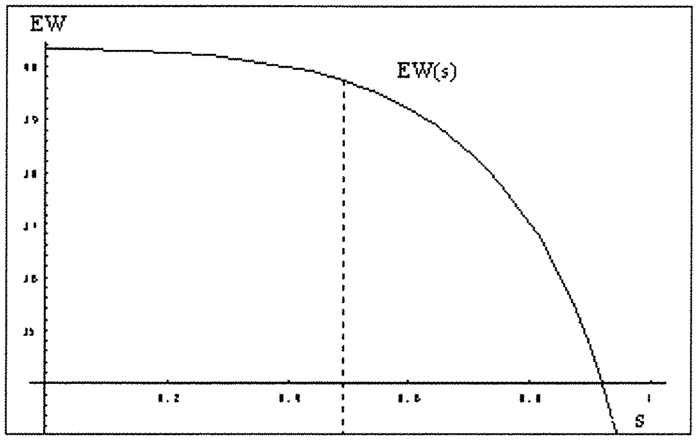

Figure 3.9: Graph of Welfare: Full public ownership remains optimal.

cost one would expect the government to sell sufficient equity to give the owner-manager control of the firm. As a minimum sale of fifty per cent of equity is required to induce some effort I would expect a cluster of privatisation sales at this level.

3.4 Final Remarks

The level of partial privatisation is important in determining government incentives for price regulation and the amount of sunk effort undertaken by the manager of a partially privatised firm. Neither full public ownership nor complete privatisation is desirable as the government expropriates all the returns from cost-reducing effort and therefore no effort is undertaken. This depends on the assumption of high costs under full public ownership. Nevertheless this indicates that partial privatisation may be an important means of establishing commitment to high regulated prices and giving private managers more powerful effort incentives

I have been concerned with finding the optimal level of privatisation by the government, who also regulates the firm once privatisation has taken place. This involves a trade-off between allocative efficiency, raising revenues and productive efficiency. As more shares are sold to the owner-manager of a privatised monopoly she receives a greater proportion of the firm's profits and has improved incentives for productive efficiency. This raises the value of the firm and the levels of revenue obtained by the government. On the other hand, the government becomes more concerned with improving allocative efficiency, which increases the risk of expropriation and thereby depresses the firm's value. The optimal level of privatisation must trade off these effects.

Several factors seem to be important in determining the outcome of this relationship. An increase in the shadow price of public funds typically leads to a higher level of privatisation. It raises the government's concerns for productive efficiency, such that it chooses to sell more equity to the owner-manager. An increase in the difference in costs between states raises the optimal level of privatisation, $\widehat{s}$. As the cost difference increases the government becomes more concerned with productive efficiency and again chooses to sell a higher level of equity, $\widehat{s}$. An increase in the cost of effort reduces the optimal level of privatisation, $\widehat{s}$. As the cost of effort increases the marginal benefit of selling equity declines. The government chooses to retain a greater proportion of the firm's shares.

Clearly, for monopoly industries there are important benefits from the government retaining equity in the firms it privatises. The retention of equity brings its interests closer in line with those of the private shareholders and thereby deters expropriation of rents from cost-reducing effort. As such a government may obtain a higher level of consumer surplus and revenues than under complete privatisation. Many important sunk investment projects may take place which would otherwise have been neglected.

I have considered two extensions to my model. Firstly, if the distortionary effect of government taxes (the shadow cost of public funds) is falling there is an extra incentive to sell shares. The government can use the privatisation mechanism to obtain profits upfront, when they are associated with a higher shadow price.

Secondly, if the government retains control of the partially privatised firm when less than fifty per cent of its equity is sold, there will be no efficiency gains from small levels of privatisation. As such one may expect a cluster of privatisation sales of approximately fifty per cent of the firm's equity in order to induce the minimum level of effort from private managers.

Appendix A Privatisation to Passive Investors

The privatisation of a monopolistic firm is modelled as an infinitely repeated stage game. The firm is initially under public ownership. It faces demand $q(p_i)$. The marginal operating cost is constant and equal to c, and there are no fixed costs. λ_i is the shadow price of public funds. This reflects the distortionary effects of taxes levied to raise extra government revenue. The privatisation process is characterised as follows: At the beginning of each stage the government has the option of selling a proportion, s_i, of its remaining equity in the firm. It then sets a regulated price, p_i, which will hold for the remainder of the period. Profits are distributed to shareholders (including the government) in the form of dividends. This stage game is repeated an infinite number of times.

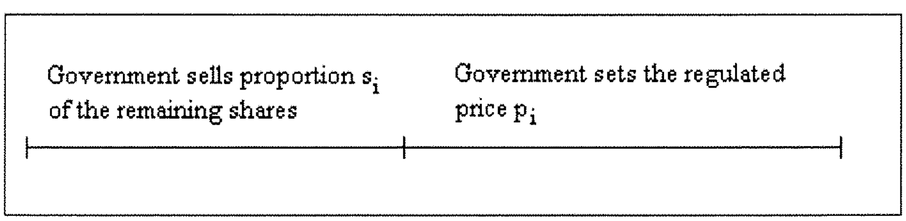

Figure 3.10: Stage Move Order

The government seeks to maximise the expected value of its objective function, which is the discounted value of future consumer surplus, private shareholders' utility, the proceeds from privatisation sales and the dividends from its shareholdings.

$$W_t = \sum_{i=t}^{\infty} \delta^{i-t} \left\{ V(p_i) + U(p_i) + (1+\lambda_i)s_i\Pi_i + (1+\lambda_i)(b_i - s_i)\pi_i(p_i) \right\}, \qquad \text{(A3.1)}$$

where $V(p_i)$ is consumer surplus, $U(p_i)$ is the private shareholders' utility, p_i is the price of output in period i, and s_i is the proportion of equity that is sold in that period. Π_i is the value of the firm, b_i is the proportion of equity still held by the government at the beginning of period i and $\pi_i(p_i) = q(p_i)(p_i - c)$ is the level of profits. δ is the discount factor.

The private shareholders' utility in period i is

$$U_i(p_i) = (1 - (b_i - s_i))\pi_i(p_i) - s_i\Pi_i.$$

Substituting this into equation (A3.1) I obtain

$$W_t = \sum_{i=t}^{\infty} \delta^{i-t} \left\{ V(p_i) + \lambda_i s_i \Pi_i + (1 + \lambda_i(b_i - s_i))\pi_i(p_i) \right\}.$$

The private shareholders are assumed to be passive investors who are willing to pay a price equal to the discounted value of expected future profits. They have the same information as the government. The value of the firm in period i is therefore:

$$\Pi_i = \pi(p_i) + \delta\Pi_{i+1}.$$

I assume that the shadow price of public funds is declining over time. ($\lambda_1 \geq \lambda_2 \geq \lambda_3 ... \geq \lambda_n$.) This reflects a deep shortage of revenue during the early stages of the privatisation programme.

I shall firstly determine the optimal privatisation process when the government can commit to its future pricing policy and then consider the case when the government is unable to commit to future regulated prices.

Appendix A.1 Commitment Case

Suppose the government is able to commit to its future pricing policies and privatisation sales. At the beginning of the game the government chooses the optimal amount of shares to sell in each period, s_i, and the optimal price for each period, p_i.

It maximises its first-period objective function with respect to s_i and p_i.

$$\begin{aligned}\max_{b_i \geq s_i \geq 0,\ p_i} W_1 &= \sum_{i=1}^{\infty} \delta^{i-1} \left\{ V(p_i) + \lambda_i s_i \Pi_i + (1 + \lambda_i(b_i - s_i))\pi_i(p_i) \right\} \\ \text{where } \Pi_i &= \pi_i(p_i) + \delta \Pi_{i+1}\ ,\ b_{i+1} = b_i - s_i,\ b_1 = 1 \text{ and } b_i \geq 0.\end{aligned}$$

Rewriting the objective function I obtain:

$$\begin{aligned}\max_{b_i \geq s_i \geq 0,\ p_i} W_1 &= \sum_{i=1}^{\infty} \delta^{i-1} \left\{ V(p_i) + \lambda_i \delta s_i \Pi_{i+1} + (1 + \lambda_i b_i)\pi_i(p_i) \right\} \\ \text{where } \Pi_i &= \pi_i(p_i) + \delta \Pi_{i+1},\ b_{i+1} = b_i - s_i,\ b_1 = 1 \text{ and } b_i \geq 0.\end{aligned}$$

I find the optimal share sales for the government in the first period of the game by maximising W_1 with respect to s_1.

$$\begin{aligned}\frac{dW_1}{ds_1} &= \delta \lambda_1 \Pi_2 - \sum_{i=2}^{\infty} \delta^{i-1} \lambda_i \pi_i(p_i) \\ &= \sum_{i=2}^{\infty} \delta^{i-1} (\lambda_1 - \lambda_i) \pi_i(p_i) > 0 \\ &\Rightarrow\ s_1 = 1,\ b_2 = 0.\end{aligned}$$

Given a shadow price that is declining over time (i.e. $\lambda_1 \geq \lambda_2 \geq \lambda_3 ... \geq \lambda_n$) the government sells all of the firm's equity in the first period. There is immediate full privatisation. By selling all of the firm's shares upfront the government obtains the discounted sum of future profits as privatisation revenues, which are associated with a higher shadow price. If it retains some shares it receives part of the profits as dividends at a later date when there is a lower shadow price. Under full commitment selling shares will have no effect on future regulated prices and therefore on profits so immediate full privatisation will always be optimal.

Given $s_1 = 1$ I can rewrite the government's objective function as follows:

$$W_1 = \sum_{i=1}^{\infty} \delta^{i-1} [V(p_i) + (1 + \lambda_1)\pi(p_i)]$$

Maximising with respect to p_i I obtain:

$$\begin{aligned}\frac{dW_1}{dp_i} &= -\delta^{i-1}q(p_i) + (1+\lambda_1)\delta^{i-1}(q(p_i) + q'(p_i)(p_i - c)) = 0 \\ &\Rightarrow \frac{p_i - c}{p_i} = \frac{\lambda_1}{(1+\lambda_1)\eta},\end{aligned}$$

where $\eta = \dfrac{q'p}{q}$ is the elasticity of demand. This is simply a form of Ramsey Pricing where λ_1 is the shadow price of public funds in the first period. Given $\lambda_1 > 0$, the price in each period is greater than marginal cost and there are positive profits.

Appendix A.2 No Commitment Case

I now assume that the government is unable to commit to the regulated price it will set in future periods. The shadow price of public funds takes a high value, λ_H, in period 1 and then falls to a lower value, λ_L, in period 2 and remains constant for the rest of the game.

The government sets the price in each period to maximise its current welfare. Any privatisation revenues have already been obtained by the government and are therefore not taken into account in making these decisions. The optimal price is:

$$\widehat{p}_i(\alpha_i) = \arg\max V(p_i) + \alpha_i \pi(p_i) \text{ s.t. } p_i - c \geq 0,$$

where $\alpha_i = (1 + \lambda_i(b_i - s_i))$.

$$\widehat{p}_i(\alpha) = \begin{cases} z_i(\alpha_i) & \text{if } \alpha_i > 1 \\ c & \text{if } \alpha_i \leq 1 \end{cases},$$

where $z_i(\alpha_i)$ satisfies $\dfrac{z_i(\alpha_i) - c}{z_i(\alpha)} = \dfrac{\alpha_i - 1}{\alpha_i \eta}$ and $\eta = \dfrac{pq'}{q}$ is the elasticity of demand. This is a form of Ramsey Pricing taking into account the level of privatisation. The government sets a price above marginal cost if it retains any equity in the firm. (i.e. if $\alpha_i > 1$) Otherwise the price is set equal to marginal cost and profits are equal to zero.

I can define a value function:

$$\psi(\alpha_i) = \max_{p_i} V(p_i) + \alpha_i \pi(p_i),$$

which is convex in α. By the envelope theorem $\psi'(\alpha_i) = \pi(\widehat{p}_i(\alpha_i))$.

The government chooses the amount of shares to sell in each period, s_i, to maximise its future welfare. I shall initially determine the optimal level of share sales in each period once the shadow price has become constant at λ_L (i.e. from period 2 onwards) using a Bellman Equation. I shall then consider the number of shares which are sold in the first period.

Assume that the proportion of shares still held by the government after period 1 is b. The Bellman Equation is then:

$$W(b) = \max_{b \geq s \geq 0} \left\{ \left\{ \psi(1 + \lambda_L(b - s)) + \frac{s\lambda_L \psi'(1 + \lambda_L(b - s))}{1 - \delta} \right\} + \delta W(b - s) \right\}.$$

A possible candidate solution is $s = 0$. (i.e. no shares are sold once λ_i becomes constant.) I then have the following value function:

$$W(b) = \begin{array}{cc} \dfrac{\psi(1 + \lambda_L b)}{1 - \delta} & \text{if } b > 0 \\ \dfrac{V(c)}{1 - \delta} & b = 0 \end{array}.$$

If some shares are retained the regulated price will be greater than cost and there will be positive profits in each period. For b equal to zero the price is set equal to cost and there will be zero profits. Consumer surplus is simply $V(c)$.

Substituting the value function into the Bellman Equation I obtain:

$$\begin{aligned} & \frac{\psi((1 + \lambda_L b)}{1 - \delta} \\ = & \max_{b \geq s \geq 0} \left\{ \begin{array}{c} \left\{ \psi(1 + \lambda_L(b - s)) + \dfrac{\lambda_L s \psi'(1 + \lambda_L(b - s))}{1 - \delta} \right\} \\ + \dfrac{\delta}{1 - \delta} \psi(1 + \lambda_L(b - s)) \end{array} \right\} \\ = & \max_{b \geq s \geq 0} \left\{ \frac{\psi(1 + \lambda_L(b - s))}{1 - \delta} + \frac{\lambda_L s \psi'(1 + \lambda_L(b - s))}{1 - \delta} \right\}. \end{aligned}$$

for $b > 0$

Maximising the right-hand-side with respect to s I obtain:

$$\frac{-s\lambda_L^2\psi''(1+\lambda_L(b-s))}{1-\delta}=0$$
$$\Rightarrow \quad s=0$$

The right-hand side of the Bellman equation is therefore maximised at $s=0$. The Bellman equation is satisfied for $s=0$. (For the case where $b=0$ the objective function is independent of s. $\psi'(1)=0$ and $W_1=\frac{V(c)}{1-\delta}$.) Once the shadow price of public funds becomes constant the government has no incentive to sell any more shares. It retains any shares it currently holds. By selling extra shares the government causes a reduction in the future price of output and profits, and profits are redistributed between future dividends and privatisation revenues. As the current choice of price already maximises welfare the government will not benefit from additional share sales.

Now consider how many shares the government will sell in the first period. The government chooses the proportion of shares to sell in period 1, s_1, to maximise its objective function. Given that no equity is sold once the shadow price becomes constant the objective function can be written as follows:

$$\begin{aligned}W_1(s_1) &= \psi(1+\lambda_H(1-s_1))+\beta\psi(1+\lambda_L(1-s_1))\\ &+s_1\lambda_H\left\{\psi'(1+\lambda_H(1-s_1))+\beta\psi'(1+\lambda_L(1-s_1))\right\}.\end{aligned}$$

where $\beta=\frac{\delta}{1-\delta}$.

Differentiating with respect to s_1 I obtain:

$$\begin{aligned}\frac{dW_1}{ds_1} &= (\lambda_H-\lambda_L)\beta\psi'(1+\lambda_L(1-s_1))-s_1\lambda_H^2\psi''(1+\lambda_H(1-s_1))\\ &\quad -s_1\beta\lambda_H\lambda_L\psi''(1+\lambda_L(1-s_1))=0.\end{aligned}$$

$$\Rightarrow \text{If either } \delta=0 \text{ or } \lambda_H=\lambda_L \text{ then } s_1=0.$$

If the government is only concerned with first period welfare there will be no share sales. The firm will be retained in public ownership. If the government sells any shares it will set the ex-post regulated price below the ex-ante optimal price, and ex-ante welfare will be reduced. Similarly with a constant shadow price in all periods there will be no share sales. Selling shares simply redistributes revenues between privatisation revenues and dividends which are associated with the same shadow price.

For a positive discount rate ($0 < \delta \leq 1$) and a higher shadow price in the first period than in all subsequent periods ($\lambda_H > \lambda_L > 0$) there will be positive share sales.

$$\begin{aligned} \left.\frac{dW_1}{ds_1}\right|_{s_1=0} &= (\lambda_H - \lambda_L)\beta\psi'(1 + \lambda_L)) > 0. \\ &\Rightarrow s_1 > 0. \end{aligned}$$

The government sells shares to obtain the discounted sum of future profits as privatisation revenues, which are associated with a higher shadow price. However, selling shares also causes the future price of output to be reduced below the ex-ante optimal level. The optimal level of share sales in the first period must trade off these two effects.

Chapter 4

Regulation, Liberalisation, and Capture. When is it Optimal to Liberalise an Industry? When is it Optimal to Regulate Entry?

4.1 Introduction

Two important issues for the regulation of firms with market power are the effects of asymmetric information on the choice of whether to regulate or liberalise an industry and the effects of regulatory capture on entry decisions. Firms are typically better informed than regulators about demand, cost conditions, or the level of cost-reducing effort. If such asymmetries are present marginal cost pricing typically becomes difficult and the regulator will face a trade-off between allocative efficiency, productive efficiency and minimising adverse distributional effects. Under such circumstances it may be preferable to liberalise an industry rather than to pursue inefficient regulation of a monopolistic firm. Informational asymmetries may also give rise to problems of regulatory capture and thereby influence entry decisions. Firms may bribe a regulator to restrict the level of entry into an industry and raise their rents. The government may in turn offer incentive schemes to the regulator to discourage collusion with the firms. The outcome depends on the relative power of the incentive schemes. If the costs of capture are sufficiently high it may be preferable for the government to adopt free-entry into the industry rather than to allow regulated entry.

The traditional theories of regulation assume that regulators are benevolent social-welfare maximisers constrained by informational asymmetries. Baron and Myerson (1982) consider the problem of how to regulate a monopoly with unknown but exogenous costs. The regulator sets an incentive scheme for the firm to induce it to reveal its costs truthfully. However, the firm's private information allows it to obtain some informational rents. The optimal regulated price is above marginal cost, sacrificing some allocative efficiency in order to reduce the firm's rents and improve distributional efficiency. Laffont and Tirole (1986) examine the related problem of regulating a firm whose cost-reducing effort is unobservable. There are a continuum of types of risk-neutral firm whose costs are only observed with noise. The firm is informed as to its own costs, but the regulator has only a prior probability concerning the firm's true type. A relatively efficient firm is therefore able to gain rents by mimicking a less efficient type and setting a lower level of effort. Optimal regulation with asymmetric cost information therefore involves a trade-off between giving powerful effort incentives and minimising informational rents. If there is asymmetric demand information, however, the conclusions are very different. Lewis and Sappington (1988a) show that when marginal costs are increasing in output the informational asymmetry is unimportant. The regulator can induce the firm to use its superior information in the social interest, thereby achieving the first-best outcome. In contrast, when marginal costs are declining in output it is no longer optimal to delegate any pricing authority to the firm. The regulator sets a single regulated price which is independent of output. If the welfare loss from such demand or cost asymmetries is sufficiently high it may be preferable to liberalise the industry. Competition has important benefits in terms of improving allocative efficiency and may overcome problems of regulatory failure relating to asymmetric information.

In practice, however, it is not clear that a regulator will pursue the best interests of society rather than its own interests or those of the industry it regulates. The "capture" or "interest group" theories of regulation were first developed by Stigler (1971), Posner (1971,1974) and Peltzman (1976) and similar techniques were used by Brock, Magee and Young (1974,1975,1989) to model endogenous tariff theory. They suggest that a regulator will use its authority to benefit the most powerful interest groups. Regulated firms may offer substantial bribes or reward former regulators with lucrative directorships in return for policy concessions. Why then does the government delegate regulation to an agent? It does so because the regulator has an informational advantage, the government is politically constrained, or because the regulator is required to pursue different objectives than those of the government.

Laffont and Tirole (1993, ch. 11) argue that regulatory capture or corruption between a regulator and firm is based on asymmetric information. Without any asymmetries the regulated firm would be unable to obtain any rents and would therefore have no reason to influence the regulator. However, under asymmetric information a low cost firm can obtain rents by mimicking a high cost type. Their model of regulatory capture considers the case of a three-tier principal-agent model involving a government, a regulatory agency and a firm. There are two types of firm with high and low costs respectively. The firm is informed as to its own costs, but the regulatory agency only has a limited probability of discovering the firm's true type. The government is uninformed. The efficient type's rent gives it an incentive to bribe the agency not to reveal its information to the government. To prevent collusion the government must reduce the efficient type's rent and pay a higher reward to the regulatory agency. It therefore gives a less powerful incentive scheme to the inefficient type of firm than in the absence of collusion and social welfare is reduced.

Regulatory capture may have important effects on the regulation of entry into an industry. Laffont and Tirole (1993, ch. 13) consider the case of an incumbent monopolist with private information concerning its costs. The regulator chooses whether or not to allow entry by a firm producing a differentiated product. Entry may be socially beneficial as it increases the variety of products or harmful because it leads to a duplication of fixed costs. The government has no information concerning the desirability of entry and therefore relies on the agency. Since the incumbent's informational rent is higher when entry is denied it will bribe the regulator to restrict entry. Given a passive principal regulation results in the monopolisation of the industry. However, given an active principal the threat of capture may increase the probability of entry.

Existing rents are not a necessary condition for corruption or capture. Bliss and Di Tella (1997) show that corruption may affect the number of firms in a free-entry equilibrium. Corrupt officials may demand payments from firms in return for licenses to operate. These payments raise the firms' costs and force some of them to exit the industry thereby lowering the number of firms in a free-entry equilibrium. The remaining firms will earn sufficient rents to pay off the officials.

The purpose of this chapter is to consider two important problems: Firstly, I extend the Baron-Myerson model to examine the optimal regulatory policy for an industry when the incumbent has private information and is given the choice of whether or not to liberalise. A regulated monopoly is inefficient because the regulator must compromise between allocative and distributional efficiency. Mankiw and Whinston (1986) show that free-entry is socially inefficient because it leads to the duplication of fixed set-up costs. I determine endogenously the conditions under which it is preferable to liberalise an industry rather than to maintain a regulated monopoly. Both unobservable marginal costs and unobservable fixed costs are considered. Secondly, I use an alternative application of my model to examine the regulator's choice of entry into an industry when the cost structure is unknown and the regulator is captured by the firms it is designed to regulate. I determine endogenously the conditions under which it is preferable to adopt free-entry rather than allow the regulator to control the level of entry into an industry. The regulator has private information concerning the industry's costs and has an incentive to manipulate the entry decision to generate high profits for the industry. The government must therefore design an incentive scheme for the regulator to induce it to set entry as close as possible to the socially optimal level.

The two models developed in this chapter are equivalent in terms of the agents involved. In my first model, without capture, one agent (the regulator) aims to maximise social welfare and is uninformed about one cost parameter (either marginal or fixed costs); the other agent (the firm) aims to maximise its profits and is fully informed about costs. In my second model, with regulatory capture, the agents have the same objectives and information but are now relabelled the 'government' and the 'captured regulator/firms' respectively. The key difference is not regulatory capture, but that a different incentive schedule is offered to the second agent in each case. In the former model the regulatory schedule is a function of output, in the latter, a function of the number of firms that enter the industry. It is not possible to say in advance which schedule is more appropriate. By looking at them separately it is possible to concentrate on different aspects of regulation. A quantity regulatory schedule is used in the first model to determine when it is preferable to liberalise an industry rather than to maintain a regulated monopoly. An entry schedule is used in the second model to determine when it is preferable to allow free-entry into an industry rather than to regulate the level of entry. It would not be possible to separate these issues in a model combining both types of schedule.

In section 4.2 I examine the relative benefits of liberalisation and maintaining a regulated monopoly. In section 4.3 I examine the effects of regulatory capture and determine when it is optimal for the government to adopt free-entry into an industry rather than to allow regulated entry. Finally, a summary of my results and final remarks are given in section 4.4.

4.2 Monopoly Regulation versus Liberalisation

4.2.1 Unobservable marginal costs

The purpose of this model is to examine the optimal regulatory policy for an industry when the incumbent monopolist has private information and is given the choice of whether or not to liberalise. This allows me to determine when it is optimal to regulate a monopolistic firm rather than liberalise the industry. The incumbent has two choices: it can either choose to produce the quantity, Q, and retain its monopoly or it can allow free-entry into the industry. The regulator's problem is to design the optimal incentive scheme for the firm, when either marginal costs or fixed costs are unobservable, in order to prevent the firm from deviating too far from the socially optimal policy.

I shall firstly consider the case of unobservable marginal costs and then extend the model to unobservable fixed costs. I assume that there is an incumbent monopolist with a constant unit cost, θ, and a fixed set-up cost F. There are an infinite number of number of potential entrants with the same technology as the incumbent. If entry takes place the firms compete under Cournot competition. The incumbent knows the true value of the cost parameter θ, but that θ is not known to the regulator. I assume that the regulator has a prior probability distribution on the cost parameter θ which is summarised by the density function $g(\theta)$ with support $[\underline{\theta},\overline{\theta}]$. $G(\theta)$ is the cumulative distribution function. The hazard rate, $H(\theta) = \dfrac{G(\theta)}{g(\theta)}$, is monotonically increasing in θ.

I recognise that with identical firms it is possible to obtain the first-best solution through an auction mechanism whereby the firm that offers the lowest price to consumers wins the license to produce in the industry and receives a subsidy equal to the fixed set-up cost, F. However I am primarily interested in comparing the outcomes under price regulation of a monopolistic firm and liberalisation, and determining when it is optimal to liberalise. So I ignore the possibility of allocating production using auctions.

The inverse demand function, $P(Q) = a - bQ$, is assumed to be known by all parties, so that $P(Q)$ is the price at which consumers demand output Q. I assume that $a, b > 0$. The total value to consumers of output Q is the area under the demand curve, given by

$$U(Q) = \int_0^Q P(\widetilde{Q})d\widetilde{Q}.$$

Consumer surplus is $V(Q) = U(Q) - P(Q)Q$ and profits with a single firm are equal to $\Pi(Q, \theta) = (P(Q) - \theta)Q - F$. Under free-entry the equilibrium levels of output, prices and consumer surplus are respectively:

$$Q = \frac{1}{b}(a - \theta - \sqrt{bF}),$$

$$P = \theta + \sqrt{bF},$$

and

$$V = \frac{1}{2b}(a - \theta - \sqrt{bF})^2.$$

I assume that F is always sufficiently small compared to θ for it to be optimal for at least 3 firms to enter the industry in the free-entry equilibrium.[1]

The regulator sets its incentive scheme for the incumbent to maximise a function of consumer and producer surplus. Without loss of generality the incentive scheme takes the following form: if the incumbent chooses to liberalise it receives the transfer T_F. If the incumbent chooses to retain its monopoly and set output it receives the transfer $T(Q)$, which is a function of the level of output. The regulator uses the transfer scheme to induce the incumbent to set its choices as close as possible to socially optimal policy.

[1] It is assumed that $F \leq \dfrac{(a - \theta)^2}{16b}$.

Given the incentive scheme $\{T_F, T(Q)\}$ the incumbent's surplus will be:

$$S = \begin{cases} S(\theta) = \max_Q \Pi(Q,\theta) + T(Q) & \text{if it chooses to set output} \\ T_F & \text{if it chooses to liberalise the industry} \end{cases}.$$

The incumbent will choose to liberalise for all θ for which $T_F > S(\theta)$. Since $S(\theta)$ satisfies the envelope condition $S'(\theta) = -Q(\theta)$ it must be decreasing in θ. The incumbent will therefore choose to liberalise for all $\theta > \widetilde{\theta}$, where $\widetilde{\theta}$ satisfies the condition $S(\widetilde{\theta}) = T_F$. For $\theta \leq \widetilde{\theta}$ the incumbent will choose to retain its monopoly and set the level of output. The threshold cost between monopoly regulation and liberalisation, $\widetilde{\theta}$, is shown in Figure 4.1. By appropriate choice of the transfer scheme $\{T_F, T(Q)\}$ the regulator can determine the range of costs over which the incumbent chooses to liberalise. The incumbent's surplus can now be written as

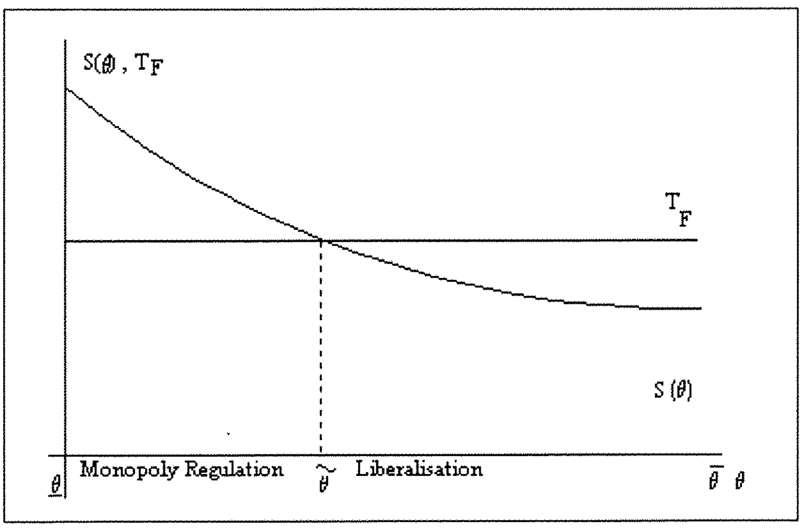

Figure 4.1: Threshold cost between regulation and liberalisation

$$S = \begin{cases} S(\theta) = (P(Q(\theta)) - \theta)Q(\theta) - F + T(Q(\theta)) & \text{for } \theta \leq \widetilde{\theta} \\ S(\widetilde{\theta}) = (P(Q(\widetilde{\theta})) - \widetilde{\theta})Q(\widetilde{\theta}) - F + T(Q(\widetilde{\theta})) & \text{for } \theta > \widetilde{\theta} \end{cases}. \tag{4.1}$$

I find the incumbent's informational rent by integrating the envelope condition $S'(\theta) = -Q(\theta)$ with respect to θ. The incumbent's surplus is

$$S(\theta) = S(\widetilde{\theta}) + \int_{\theta}^{\widetilde{\theta}} Q(\widehat{\theta}) d\widehat{\theta}, \tag{4.2}$$

for $\theta \leq \widetilde{\theta}$, where the integral is the firm's informational rent. The informational rent is equal to zero for $\theta > \widetilde{\theta}$. I assume that the incumbent will simply shut down if it expects a negative surplus. So regulatory policy must satisfy the incumbent's individual rationality constraint

$$S(\theta) \geq 0 \tag{4.3}$$

for all θ in $[\underline{\theta},\overline{\theta}]$.

Expected consumer surplus is

$$E_\theta V(\theta) = \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}} (a - \theta - \sqrt{bF})^2 dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \frac{b}{2} Q(\theta)^2 dG(\theta),$$

and the incumbent's expected surplus is

$$\begin{aligned} E_\theta S(\theta) &= \int_{\widetilde{\theta}}^{\overline{\theta}} S(\widetilde{\theta}) dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} S(\theta) dG(\theta) \\ &= \int_{\widetilde{\theta}}^{\overline{\theta}} T_F dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \left\{(P(Q(\theta)) - \theta)Q(\theta) - F + T(Q(\theta))\right\} dG(\theta). \end{aligned}$$

The regulator maximises a weighted sum of consumer surplus and the incumbent's surplus minus the cost of transfers. The regulator's objective is to maximise

$$\begin{aligned} &E_\theta W(\theta) = \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}} (a - \theta - \sqrt{bF})^2 dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \frac{b}{2} Q(\theta)^2 dG(\theta) \\ &+\alpha \int_{\underline{\theta}}^{\widetilde{\theta}} \left\{(P(Q(\theta)) - \theta)Q(\theta) - F\right\} dG(\theta) \\ &-(1-\alpha)\int_{\widetilde{\theta}}^{\overline{\theta}} T_F dG(\theta) - (1-\alpha)\int_{\underline{\theta}}^{\widetilde{\theta}} T(Q(\theta)) dG(\theta), \end{aligned} \tag{4.4}$$

where α is the weight on the incumbent's surplus. It is assumed that $0 \leq \alpha \leq 1$.

Solution

I shall firstly state the first-best solution for regulation which acts as a benchmark for my results under asymmetric information. Under perfect information the regulator sets the price equal to marginal cost,

$$P(Q(\theta)) = \theta,$$

and pays the incumbent a transfer equal to the level of fixed costs. The first-best level of output,

$$\widehat{Q}(\theta) = \frac{(a-\theta)}{b},$$

is greater than the free-entry equilibrium output,

$$Q_F(\theta) = \frac{1}{b}(a - \theta - \sqrt{bF}).$$

Monopoly regulation is always optimal.[2]

I shall now derive the optimal policy under asymmetric information. The following lemma simplifies the regulator's objective function.

Lemma 1 *At the optimal regulatory policy the regulator's objective function may be written as*

$$\begin{aligned} E_\theta W(\theta) &= \frac{1}{2b}\int_{\tilde{\theta}}^{\overline{\theta}} (a-\theta-\sqrt{bF})^2 dG(\theta) + \int_{\underline{\theta}}^{\tilde{\theta}} \frac{b}{2} Q(\theta)^2 dG(\theta) \\ &\quad + \int_{\underline{\theta}}^{\tilde{\theta}} \{(P(Q(\theta)) - \theta)Q(\theta) - F\}\, dG(\theta) - (1-\alpha)\int_{\underline{\theta}}^{\tilde{\theta}} Q(\theta)H(\theta)\, dG(\theta). \end{aligned} \tag{4.5}$$

Proof. From the definition of S in equation (4.1) I have

$$T(Q(\theta)) = S(\theta) - \Pi(Q(\theta)) \tag{4.6}$$

[2] Welfare under monopoly regulation is $\frac{1}{2b}(a-\theta)^2 - F$. Welfare under liberalisation is $\frac{1}{2b}(a - \theta - \sqrt{bF})^2$. Monopoly regulation is always optimal if the following condition holds for all θ. $F \leq \frac{4(a-\theta)^2}{9b}$. This is satisfied by my assumption for the free-entry equilibrium.

and

$$T_F = S(\widetilde{\theta}).$$

It is optimal for the participation constraint to bind for the least efficient industry so I have

$$T_F = S(\widetilde{\theta}) = 0. \tag{4.7}$$

Integrating by parts it follows further that

$$\int_{\underline{\theta}}^{\widetilde{\theta}} S(\theta)dG(\theta) = [S(\theta)G(\theta)]_{\underline{\theta}}^{\widetilde{\theta}} + \int_{\underline{\theta}}^{\widetilde{\theta}} Q(\theta)H(\theta)\,dG(\theta)$$

$$= \int_{\underline{\theta}}^{\widetilde{\theta}} Q(\theta)H(\theta)dG(\theta). \tag{4.8}$$

Substituting equations (4.6), (4.7), and (4.8) into equation (4.4) and re-arranging gives equation (4.5) above. Q.E.D.

I can now derive the optimal quantity scheme Q^* and the optimal threshold cost $\widetilde{\theta}^*$. The optimal quantity schedule for the regulated monopoly is found by choosing $Q(\theta)$ to maximise

$$\frac{b}{2}Q(\theta)^2 + (P(Q(\theta)) - \theta)Q(\theta) - F - (1-\alpha)Q(\theta)H(\theta).$$

For the choice of $Q(\theta)$ to be globally optimal $S(\theta)$ must be a convex function of θ. This in turn requires that $Q(\theta)$ is decreasing in θ. The assumption of a monotone hazard rate is sufficient to meet this condition. The optimal threshold cost $\widetilde{\theta}^*$ is then found by maximising the regulator's objective function with respect to $\widetilde{\theta}$. Since welfare in single-peaked in $\widetilde{\theta}$ over the support $[\underline{\theta},\overline{\theta}]$ the choice of $\widetilde{\theta}^*$ will be globally optimal. (See appendix A.)

The welfare-maximising solution can be stated as follows:

The welfare-maximising scheme for output is given by

$$Q^* = \begin{cases} Q^*(\theta) & \text{for } \theta \leq \widetilde{\theta} \\ Q_F(\theta) & \text{for } \theta > \widetilde{\theta} \end{cases},$$

where

$$Q^*(\theta) = \frac{1}{b}(a - \theta - (1-\alpha)H(\theta)) \tag{4.9}$$

and

$$Q_F(\theta) = \frac{1}{b}(a - \theta - \sqrt{bF}).$$

For marginal costs less than or equal to $\widetilde{\theta}$ the incumbent retains its monopoly and chooses the level of output $Q^*(\theta)$. This is the standard Baron-Myerson result for pricing. The price is set equal to the sum of the incumbent's marginal information and production costs. There is marginal cost pricing for the lowest realisation of costs $\underline{\theta}$. For marginal costs higher than the threshold cost $\widetilde{\theta}$ the incumbent chooses to liberalise the industry and the equilibrium level of output is $Q_F(\theta)$.

The welfare-maximising threshold cost between monopoly regulation and liberalisation is given by

$$\min[\widetilde{\theta}^*, \overline{\theta}], \tag{4.10}$$

where $\widetilde{\theta}^*$ satisfies the first-order condition

$$\begin{aligned} \frac{dE_\theta W(\theta)}{d\theta} &= -\frac{1}{2b}(a - \widetilde{\theta}^* - \sqrt{bF})^2 + \frac{b}{2}Q^*(\widetilde{\theta}^*)^2 \\ +(P(Q^*(\widetilde{\theta}^*)) - \widetilde{\theta}^*)Q^*(\widetilde{\theta}^*) - F - (1-\alpha)Q^*(\widetilde{\theta}^*)H(\widetilde{\theta}^*) &= 0. \end{aligned} \tag{4.11}$$

The marginal benefit of increasing the threshold $\widetilde{\theta}$ is the welfare under monopoly regulation minus the welfare under liberalisation given the marginal cost $\widetilde{\theta}$. Welfare under monopoly regulation is equal to the sum of consumer surplus and profits minus the weighted informational rent. Welfare under liberalisation is simply consumer surplus at the free-entry equilibrium price.

Substituting equation (4.9) into equation (4.11) and rearranging I find that $\widetilde{\theta}^*$ satisfies the following condition:

$$\frac{1}{2b}(a - \widetilde{\theta}^* - (1-\alpha)H(\widetilde{\theta}^*))^2 - F = \frac{1}{2b}(a - \widetilde{\theta}^* - \sqrt{bF})^2. \tag{4.12}$$

Provided that fixed costs are positive it is never optimal to liberalise the industry for all θ. Suppose that $\widetilde{\theta} = \underline{\theta}$. The left-hand side of equation (4.12) exceeds the right-hand side and it will be optimal to raise the threshold cost. Monopoly regulation is therefore optimal for the lowest realisation of marginal costs. Furthermore if the left-hand side of equation (4.12) always exceeds the right-hand side regulation will always be optimal.

Results

Under asymmetric information the regulator induces the incumbent to choose the quantity scheme Q^*. For $\theta \leq \widetilde{\theta}$ the incumbent chooses the level of output $Q^*(\theta)$. For $\theta > \widetilde{\theta}$ it chooses to liberalise the industry and the equilibrium level of output is $Q_F(\theta)$.

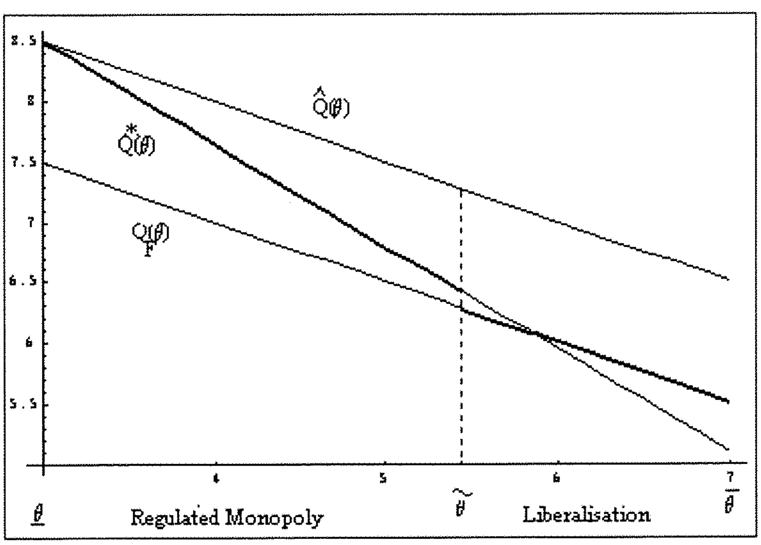

Figure 4.2: Optimal output scheme for $\alpha = 0.3$, $a = 20$, $b = 2$, $\underline{\theta} = 3$, $\overline{\theta} = 7$, $F = 2$.

The solution for output is shown as the thick line in Figure 4.2 for $\alpha = 0.3$. It is discontinuous at $\widetilde{\theta}$.

When $\alpha = 1$ regulated output $Q^*(\theta)$ is equal to the first-best level of output, $\widehat{Q}(\theta)$. There are no distortions resulting from asymmetric information. When $\alpha < 1$, however, and except for the case where the firms have the lowest possible marginal cost $\underline{\theta}$, regulated output is less than the first-best level, $\widehat{Q}(\theta)$. The regulator faces a trade-off between raising output and therefore offering lower prices to consumers and allowing greater rents to be obtained by the regulated incumbent. The greater the importance of distributional concerns - the lower is α - the lower the level of output.

In determining the threshold cost, $\widetilde{\theta}$, between monopoly regulation and liberalisation the regulator faces a trade-off between the benefits of liberalisation and the benefits of a regulated monopoly. Under liberalisation the incumbent obtains no informational rents. However, there is duplication of fixed set-up costs. Under monopoly regulation there is no duplication of fixed costs but the incumbent obtains costly informational rents. The optimal level of $\widetilde{\theta}$ will trade off these effects.

If $\alpha = 1$ it is optimal to set $\widetilde{\theta} = \overline{\theta}$ and maintain a regulated monopoly for all θ. Regulating the incumbent avoids any duplication of fixed costs and there are no informational rents. Liberalisation on the other hand leads to an inefficient duplication of fixed set-up costs.

If $F = 0$ it is always optimal to liberalise. Under liberalisation the equilibrium price is equal to marginal cost as the industry is perfectly competitive. Under monopoly regulation there is some allocative inefficiency as the price exceeds marginal cost and there are costly informational rents for the incumbent.

For $\alpha < 1$ the threshold , $\widetilde{\theta}$, between regulation and liberalisation will be determined by the degree to which the regulator is concerned with profits, the level of fixed costs, and the demand parameter b.

The threshold cost is increasing in α for $\widetilde{\theta}^* < \overline{\theta}$. (See appendix B.) As the regulator gives more weight to profits the degree of allocative inefficiency under regulation is reduced and informational rents become less costly. However, the cost of liberalisation in terms of duplicating fixed set-up costs remains constant. It is therefore optimal to maintain a regulated monopoly for a wider interval of costs.

The threshold cost is increasing in F for $\widetilde{\theta}^* < \overline{\theta}$. (See appendix B.) As fixed costs increase the cost of liberalisation is raised, while the costs of regulation remain constant. It is optimal to retain a monopoly for a wider range of costs.

Finally, the threshold cost is increasing in b for $\widetilde{\theta}^* < \overline{\theta}$. (See appendix B.) As demand becomes more elastic the cost of liberalisation increases relative to the cost of regulation and it is optimal to retain a monopoly over a wider interval of costs.

In summary where there are very strong natural monopoly conditions (there is a high level of fixed costs) or the regulator gives a high weight to profits it is always optimal to pursue monopoly regulation. More generally it is optimal to maintain a regulated monopoly for low realisations of costs and to liberalise for high realisations of costs. Only in the special case where there are no fixed costs is it always optimal to liberalise the industry. In that case the industry has perfectly competitive cost conditions.

4.2.2 Unobservable fixed costs

Now consider the case of unobservable fixed costs. Is it ever optimal to liberalise the industry? Incentive compatibility requires that liberalisation only occur for high realisations of fixed costs. However, as fixed costs grow the costs of liberalisation rise. It may be preferable to maintain a regulated monopoly for all realisations of costs.

I assume that there is a constant unit cost, c, and a fixed set-up cost θ. c is common knowledge. The incumbent knows the true value of the cost parameter θ, but θ is not known to the regulator. The regulator has a prior probability distribution on the cost parameter θ which is summarised by the density function $g(\theta)$ with support $[\underline{\theta},\overline{\theta}]$.

Demand conditions are the same as for the unknown marginal cost case. Profits with a single firm are equal to $\Pi(Q,\theta) = (P(Q) - c)Q - \theta$. Under free-entry the equilibrium levels of output, prices and consumer surplus are respectively:

$$Q = \frac{1}{b}(a - c - \sqrt{b\theta}),$$

$$P = c + \sqrt{b\theta},$$

and

$$V = \frac{1}{2b}(a - c - \sqrt{b\theta})^2.$$

It is assumed that θ is sufficiently small compared to c for it to be optimal for at least 3 firms to enter the industry in the free-entry equilibrium.[3]

The regulator sets its incentive scheme for the incumbent to maximise a function of consumer and producer surplus. Without loss of generality the incentive scheme takes the following form: if the incumbent chooses to liberalise it receives the transfer T_F. If the incumbent chooses to retain its monopoly and set output it receives the transfer $T(Q)$, which is a function of the level of monopoly output. The regulator uses the transfer scheme to induce the incumbent to set its choices as close as possible to socially optimal policy.

Given the incentive scheme $\{T_F, T(Q)\}$ the incumbent's surplus will be

$$S = \begin{cases} S(\theta) = \max_Q \Pi(Q,\theta) + T(Q) & \text{if it chooses to set output} \\ T_F & \text{if it chooses to liberalise the industry} \end{cases}.$$

The incumbent will choose liberalisation for all θ for which $T_F > S(\theta)$. Since $S(\theta)$ satisfies the envelope condition $S'(\theta) = -1$ it must be decreasing in θ. The incumbent will therefore adopt free-entry for all $\theta > \widetilde{\theta}$, where $\widetilde{\theta}$ satisfies the condition $S(\widetilde{\theta}) = T_F$. For $\theta \leq \widetilde{\theta}$ the incumbent will choose to retain its monopoly and set output. The threshold cost between monopoly regulation and liberalisation $\widetilde{\theta}$ is shown in Figure 4.3. The incumbent's surplus can now be written as:

$$S = \begin{cases} S(\theta) = (P(Q(\theta)) - c)Q(\theta) - \theta + T(Q(\theta)) & \text{for } \theta \leq \widetilde{\theta} \\ S(\widetilde{\theta}) = (P(Q(\widetilde{\theta})) - c)Q(\widetilde{\theta}) - \widetilde{\theta} + T(Q(\widetilde{\theta})) & \text{for } \theta > \widetilde{\theta} \end{cases}. \tag{4.13}$$

[3] It is assumed that $\overline{\theta} \leq \dfrac{(a-c)^2}{16b}$.

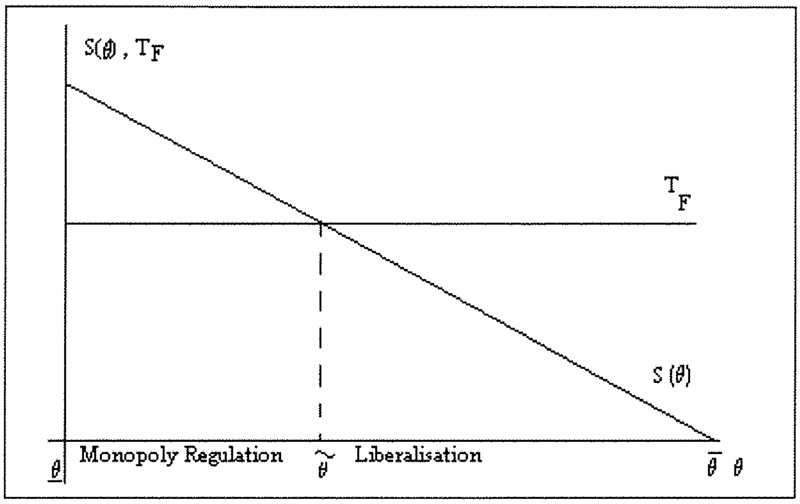

Figure 4.3: Threshold cost between a regulation and liberalisation

The incumbent's informational rent is found by integrating the envelope condition $S'(\theta) = -1$ with respect to θ. The incumbent's surplus is

$$S(\theta) = S(\widetilde{\theta}) + \int_{\theta}^{\widetilde{\theta}} d\widehat{\theta}, \tag{4.14}$$

for $\theta \leq \widetilde{\theta}$, where the integral is the firm's informational rent. The informational rent is equal to zero for $\theta > \widetilde{\theta}$. I assume that the monopoly will simply shut down if it expects a negative surplus. So regulatory policy must satisfy the incumbent's individual rationality constraint

$$S(\theta) \geq 0 \tag{4.15}$$

for all θ in $[\underline{\theta},\overline{\theta}]$.

Expected consumer surplus is

$$E_\theta V(\theta) = \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}} (a - c - \sqrt{b\theta})^2 dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \frac{b}{2} Q(\theta)^2 dG(\theta),$$

and the incumbent's expected surplus is

$$\begin{aligned}
E_\theta S(\theta) &= \int_{\widetilde{\theta}}^{\overline{\theta}} S(\widetilde{\theta})dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} S(\theta)dG(\theta) \\
&= \int_{\widetilde{\theta}}^{\overline{\theta}} T_F dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \{(P(Q(\theta)) - c)Q(\theta) - \theta + T(Q(\theta))\} \, dG(\theta).
\end{aligned}$$

I assume that the regulator maximises a weighted sum of consumer surplus and the incumbent's surplus minus the cost of transfers. The regulator's objective is to maximise

$$E_\theta W(\theta) = \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}} (a - c - \sqrt{b\theta})^2 dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \frac{b}{2} Q(\theta)^2 dG(\theta) \tag{4.16}$$

$$+\alpha \int_{\underline{\theta}}^{\widetilde{\theta}} \{(P(Q(\theta)) - c)Q(\theta) - \theta\} \, dG(\theta)$$

$$-(1-\alpha)\int_{\widetilde{\theta}}^{\overline{\theta}} T_F dG(\theta) - (1-\alpha)\int_{\underline{\theta}}^{\widetilde{\theta}} T(Q(\theta))dG(\theta).$$

Solution

I shall firstly state the first-best solution for regulation which acts as a benchmark for our results under asymmetric information. Under perfect information the regulator sets price equal to marginal cost,

$$P(Q(\theta)) = c,$$

and pays the incumbent a transfer equal to fixed costs. The first-best level of output,

$$\widehat{Q}(\theta) = \frac{(a-c)}{b},$$

is greater than the free-entry equilibrium output,

$$Q_F(\theta) = \frac{1}{b}(a - c - \sqrt{b\theta}).$$

Monopoly regulation is always optimal.[4]

I shall now derive the optimal policy under asymmetric information. The following lemma simplifies the regulator's objective function.

Lemma 2 *At the optimal regulatory policy the regulator's objective function may be written as*

$$\begin{aligned} E_\theta W(\theta) &= \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}} (a-c-\sqrt{b\theta})^2 dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}} \frac{b}{2} Q(\theta)^2 dG(\theta) \\ &\quad + \int_{\underline{\theta}}^{\widetilde{\theta}} \left\{ (P(Q(\theta)) - c)Q(\theta) - \theta \right\} dG(\theta) - (1-\alpha)\int_{\underline{\theta}}^{\widetilde{\theta}} H(\theta) dG(\theta) \end{aligned} \tag{4.17}$$

Proof. From the definition of S in equation (4.13) I have

$$T(Q(\theta)) = S(\theta) - \Pi(Q(\theta)) \tag{4.18}$$

and

$$T_F = S(\widetilde{\theta}).$$

It is optimal for the participation constraint to bind for the least efficient industry so I have

$$T_F = S(\widetilde{\theta}) = 0. \tag{4.19}$$

Integrating by parts it follows further that

$$\begin{aligned} \int_{\underline{\theta}}^{\widetilde{\theta}} S(\theta) dG(\theta) &= [S(\theta)G(\theta)]_{\underline{\theta}}^{\widetilde{\theta}} + \int_{\underline{\theta}}^{\widetilde{\theta}} H(\theta) dG(\theta) \\ &= \int_{\underline{\theta}}^{\widetilde{\theta}} H(\theta) dG(\theta). \end{aligned} \tag{4.20}$$

[4] Welfare under monopoly regulation is $\frac{1}{2b}(a-c)^2-\theta$. Welfare under liberalisation is $\frac{1}{2b}(a-c-\sqrt{b\theta})^2$. Monopoly regulation is optimal if the following condition holds for all θ.

$$\theta \leq \frac{4(a-c)^2}{9b}.$$

This condition holds given my assumption for the free-entry equilibrium.

Substituting equations (4.18), (4.19), and (4.20) into equation (4.16) and re-arranging gives us equation (4.17) above. Q.E.D.

I can now derive the optimal quantity scheme Q^* and the optimal threshold cost $\widetilde{\theta}^*$. The optimal quantity schedule for the regulated monopoly is found by choosing $Q(\theta)$ to maximise

$$\frac{b}{2}Q(\theta)^2 + (P(Q(\theta)) - c)Q(\theta) - \theta - (1-\alpha)H(\theta).$$

For the choice of $Q(\theta)$ to be globally optimal $S(\theta)$ must be a convex function of θ. This condition is satisfied as $S''(\theta) = 0$. The optimal threshold cost $\widetilde{\theta}$ is then found by maximising the regulator's objective function with respect to $\widetilde{\theta}$. The welfare function may not be single-peaked in $\widetilde{\theta}$ so a further restriction on the density function $g(\theta)$ is required. I assume that θ is uniformly distributed on $[\underline{\theta},\overline{\theta}]$.

The welfare-maximising solution can be stated as follows:

The welfare-maximising scheme for output is given by

$$Q^* = \begin{cases} Q^*(\theta) & \text{for } \theta \leq \widetilde{\theta} \\ Q_F(\theta) & \text{for } \theta > \widetilde{\theta} \end{cases},$$

where $Q^*(\theta)$ satisfies

$$P(Q^*(\theta)) = c \tag{4.21}$$

and

$$Q_F(\theta) = \frac{1}{b}(a - c - \sqrt{b\theta}).$$

For fixed costs less than or equal to $\widetilde{\theta}$ the incumbent retains its monopoly and chooses the level of output $Q^*(\theta)$. There are no distortions to output resulting from asymmetric information (price is equal to marginal cost) but the regulator must pay transfers to the monopoly to cover fixed costs. A monopoly with relatively low fixed costs is able to obtain informational rents by mimicking a high cost type. For fixed costs higher than the threshold $\widetilde{\theta}$ the incumbent chooses to liberalise the industry and the equilibrium level of output is $Q_F(\theta)$. Output is below the first-best level, but there are no informational rents for the incumbent.

Lemma 3 *If the regulator cannot observe the true value of fixed costs, θ, but knows that they are uniformly distributed on $[\underline{\theta},\overline{\theta}]$ monopoly regulation will always be optimal. ($\widetilde{\theta}^* = \overline{\theta}$.) It is never optimal to liberalise the industry.*

Proof. The first derivative of the government's objective function with respect to the threshold cost is

$$\begin{aligned}\frac{dE_\theta W(\theta)}{d\widetilde{\theta}} &= -\frac{1}{2b}(a-c-\sqrt{b\widetilde{\theta}})^2+\frac{b}{2}Q^*(\widetilde{\theta})^2 \\ &\quad +(P(Q^*(\widetilde{\theta}))-c)Q^*(\widetilde{\theta})-\widetilde{\theta}-(1-\alpha)H(\widetilde{\theta}).\end{aligned} \tag{4.22}$$

Substituting equation (4.21) into equation (4.22) and rearranging I derive the condition:

$$\frac{dE_\theta W(\theta)}{d\widetilde{\theta}}=\frac{1}{2b}(a-c)^2-\widetilde{\theta}-(1-\alpha)H(\widetilde{\theta})-\frac{1}{2b}(a-c-\sqrt{b\widetilde{\theta}})^2. \tag{4.23}$$

Given a uniform distribution for θ over $[\underline{\theta},\overline{\theta}]$ this may be rewritten as

$$\frac{dE_\theta W(\theta)}{d\widetilde{\theta}}=\frac{1}{2b}[(a-c)^2-(a-c-\sqrt{b\widetilde{\theta}})^2]-(2-\alpha)\widetilde{\theta}+(1-\alpha)\underline{\theta}.$$

Given that $(1-\alpha)\underline{\theta}$ is non-negative a sufficient condition for $\overline{\theta}$ to be the optimal threshold cost is

$$\frac{1}{2b}[(a-c)^2-(a-c-\sqrt{b\overline{\theta}})^2]-(2-\alpha)\overline{\theta}>0.$$

Simplifying this condition I obtain

$$\overline{\theta}<\frac{4(a-c)^2}{(5-2\alpha)^2b}.$$

This condition is satisfied by my assumption that it is always optimal for at least three firms to enter the industry in the free-entry equilibrium. Q.E.D.

The cost of a duplication of fixed costs under liberalisation always outweighs the cost of informational rents under monopoly regulation. There is no allocative inefficiency under regulation but some distributional inefficiency.[5]

[5]

Results

Under asymmetric information with unobservable fixed costs the regulator induces the incumbent to choose the quantity scheme Q^*. The incumbent sets the level of output $Q^*(\theta)$ for all θ in $[\underline{\theta},\overline{\theta}]$. $Q^*(\theta)$ is equal to the first-best level of output $\widehat{Q}(\theta)$ and greater than the free-entry level of output $Q^F(\theta)$. Although the regulated price is equal to marginal cost the incumbent earns some informational rents. The incumbent never chooses to liberalise the industry. The solution for output is illustrated by the

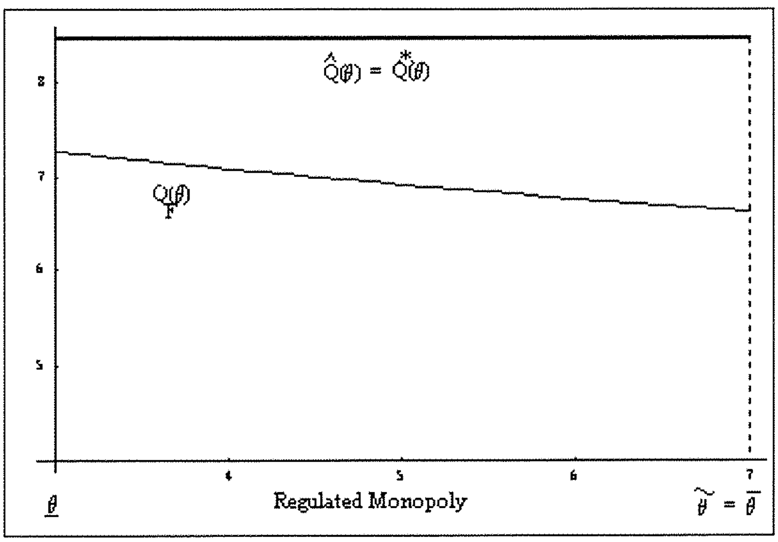

Figure 4.4: Optimal output scheme for $\alpha = 0.5$, $a = 20$, $b = 2$, $c = 3$, $\underline{\theta} = 3$, $\overline{\theta} = 7$.

thick line in Figure 4.4.

To summarise, with unobservable fixed costs it is optimal to retain a monopoly and regulate output for any realisation of costs. The cost of liberalisation in terms of duplicating fixed costs always outweighs the cost of informational rents under monopoly regulation. There is no allocative inefficiency due to regulation, but some distributional inefficiency as the firm obtains informational rents.

For other cost distributions it may be optimal to liberalise for high values of θ. Nevertheless this result provides some indication that it may be less desirable to liberalise if fixed costs are unobservable.

4.3 Regulated entry with capture versus free-entry

4.3.1 Unobservable marginal costs

This section uses an alternative interpretation of the regulation-liberalisation model to investigate the effects of regulatory capture on entry decisions. It examines the regulator's choice of entry into an industry when the regulator has private information and is captured by the firms it is designed to regulate. Regulatory capture is modelled by assuming that the regulator maximises the joint surplus of the regulatory agency and the industry. The regulator has two choices: it can either set the level of entry, n, or it can allow free-entry into the industry. The government's problem is to design the optimal incentive scheme for the regulator, when either marginal or fixed costs are unobservable, in order to prevent the regulator from straying too far from the socially optimal policy. Despite assuming a very strong form of regulatory capture I find that it is optimal for the government to allow regulated entry under many cost conditions.

I shall firstly consider the case of unobservable marginal costs and then extend the model to unobservable fixed costs. I assume that there are an infinite number of potential entrants, each with a constant unit cost, θ, and a fixed set-up cost, F. Once the firms have entered the industry they compete under Cournot competition. Both the regulator and the industry know the true value of the cost parameter θ, but θ is not known to the government. The government has a prior probability distribution on the cost parameter θ which is summarised by the density function $g(\theta)$ with support $[\underline{\theta},\overline{\theta}]$. The hazard rate $H(\theta)$ is monotonically increasing in θ. I retain the assumptions concerning demand and consumer surplus from the previous sections.

Under Cournot competition the equilibrium levels of industry output, prices, profits and consumer surplus are respectively

$$Q(n,\theta) = \frac{n(a-\theta)}{(n+1)b},$$

$$P(n, \theta) = \theta + \frac{(a - \theta)}{(n + 1)},$$

$$\Pi(n, \theta) = \frac{n(a - \theta)^2}{(n + 1)^2 b} - nF$$

and

$$V(n, \theta) = \frac{n^2(a - \theta)^2}{2(n + 1)^2 b},$$

where n is the number of firms in the industry. The free-entry equilibrium number of firms is given by:

$$n^F = \frac{(a - \theta)}{\sqrt{bF}} - 1.$$

It is assumed that F is always sufficiently small compared to θ for it to be optimal for at least 3 firms to enter the industry in the free-entry equilibrium.[6]

The government sets its incentive scheme for the regulator to maximise a function of consumer and producer surplus. Without loss of generality the incentive scheme takes the following form: if the regulator chooses free-entry it receives the transfer T_F. If it chooses to regulate entry it receives the transfer $T(n)$, which is a function of the level of entry into the industry. The government uses the transfer scheme to induce the regulator to set entry as close as possible to the socially optimal level.

Given the incentive scheme $\{T_F, T(n)\}$ the joint surplus of the regulator and the industry will be

$$S = \begin{cases} S(\theta) = \max_n \Pi(n, \theta) + T(n) & \text{if the regulator chooses entry level } n \\ T_F & \text{if the regulator chooses free-entry} \end{cases}.$$

The regulator will choose free-entry for all θ for which $T_F > S(\theta)$. Since $S(\theta)$ satisfies the envelope condition $S'(\theta) = -\dfrac{2n(\theta)(a - \theta)}{(n(\theta) + 1)^2 b}$ it must be decreasing in θ. The regulator will therefore adopt free-entry for all $\theta > \widetilde{\theta}$, where $\widetilde{\theta}$ satisfies the condition $S(\widetilde{\theta}) = T_F$. For $\theta \leq \widetilde{\theta}$ the regulator will choose to regulate entry. The threshold

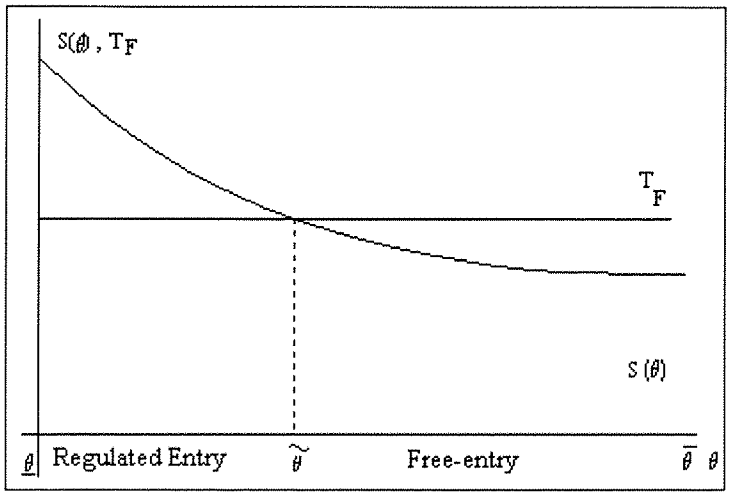

Figure 4.5: Threshold cost between regulated entry and free-entry

cost for regulation $\widetilde{\theta}$ is shown in Figure 4.5. The analysis closely follows that of the previous sections so I shall be brief here and only state the key points.

Given perfect information it is always optimal to regulate the level of entry into the industry rather than to allow free-entry. Under perfect information the government is able to extract all of the regulator and the industry's rents, so the government aims to maximise the unweighted sum of consumer surplus and profits. The government chooses $n(\theta)$ to maximise

$$W(n(\theta)) = V(n(\theta)) + \Pi(n(\theta)).$$

Following Mankiw and Whinston (1986) it is always optimal to regulate entry in this case as free-entry leads to excess duplication of fixed costs. The first-best level of entry is $\widehat{n}(\theta)$, where $\widehat{n}(\theta)$ satisfies

$$(\widehat{n}(\theta) + 1)^3 = \frac{(a-\theta)^2}{bF},$$

is less than the free-entry level,

$$n_F(\theta) = \frac{(a-\theta)}{\sqrt{bF}} - 1.$$

[6] It is assumed that $F \leq \dfrac{(a-\overline{\theta})^2}{16b}$.

Now consider the case of asymmetric information. At the optimal regulatory policy the government's objective function may be written as

$$E_\theta W(\theta) = \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}} (a-\theta-\sqrt{bF})^2 dG(\theta) \tag{4.24}$$

$$+\int_{\underline{\theta}}^{\widetilde{\theta}} \left\{ \frac{n(\theta)(n(\theta)+2)(a-\theta)^2}{2(n(\theta)+1)^2 b} - n(\theta)F - 2(1-\alpha)\frac{n(\theta)(a-\theta)}{(n(\theta)+1)^2 b} H(\theta) \right\} dG(\theta).$$

The government maximises the unweighted sum of consumer surplus and profits minus weighted informational rents. The optimal level of regulated entry is found by maximising this expression pointwise with respect to $n(\theta)$.[7] The optimal threshold cost $\widetilde{\theta}$ is found by maximising this expression with respect to $\widetilde{\theta}$.

The welfare-maximising solution can be stated as follows:

The welfare-maximising scheme for entry with capture is given by

$$n^* = \begin{cases} n^*(\theta) & \text{for } \theta \leq \widetilde{\theta} \\ n_F(\theta) & \text{for } \theta > \widetilde{\theta} \end{cases},$$

where $n^*(\theta)$ satisfies

$$(n^*(\theta)+1)^3 = \frac{(a-\theta)^2}{bF} - \frac{2}{bF}(1-\alpha)(1-n^*(\theta))(a-\theta)H(\theta)$$

and

$$n_F(\theta) = \frac{(a-\theta)}{\sqrt{bF}} - 1.$$

For marginal costs less than or equal to $\widetilde{\theta}$ the regulator chooses the level of entry $n^*(\theta)$. For marginal costs higher than the threshold $\widetilde{\theta}$ the regulator allows free-entry.

The welfare-maximising threshold cost between regulated entry and free-entry is given by

$$\min[\widetilde{\theta}^*, \overline{\theta}],$$

[7] For the solution to be implementable it is necessary that $S'(\theta) = -\frac{2n(\theta)(a-\theta)}{(n(\theta)+1)^2 b}$ is increasing in θ. This apparently cannot be verified analytically, so I have verified this condition for a wide range of numerical examples. The condition holds for all the examples considered in section 4.3.1. and I have found no counterexamples.

where $\widetilde{\theta}^*$ satisfies the first-order condition

$$\begin{aligned} -\frac{1}{2b}(a-\widetilde{\theta}^* - \sqrt{bF})^2 + \frac{n^*(\widetilde{\theta}^*)(n^*(\widetilde{\theta}^*)+2)(a-\widetilde{\theta}^*)^2}{2(n^*(\widetilde{\theta}^*)+1)^2 b} & \\ -n^*(\widetilde{\theta}^*)F - 2(1-\alpha)\frac{n^*(\widetilde{\theta}^*)(a-\widetilde{\theta}^*)}{(n^*(\widetilde{\theta}^*)+1)^2 b}H(\widetilde{\theta}^*) &= 0. \end{aligned}$$

The marginal benefit of increasing the threshold $\widetilde{\theta}$ is the welfare from regulated entry with capture minus the welfare from free-entry given the marginal cost $\widetilde{\theta}^*$.

Results

Under regulatory capture the government induces the regulator to choose the entry scheme n^*. For $\theta \leq \widetilde{\theta}$ the regulator sets the level of entry $n^*(\theta)$. For $\theta > \widetilde{\theta}$ it allows free-entry. The solution for entry is shown in Figure 4.6 for $\alpha = 0.4$.

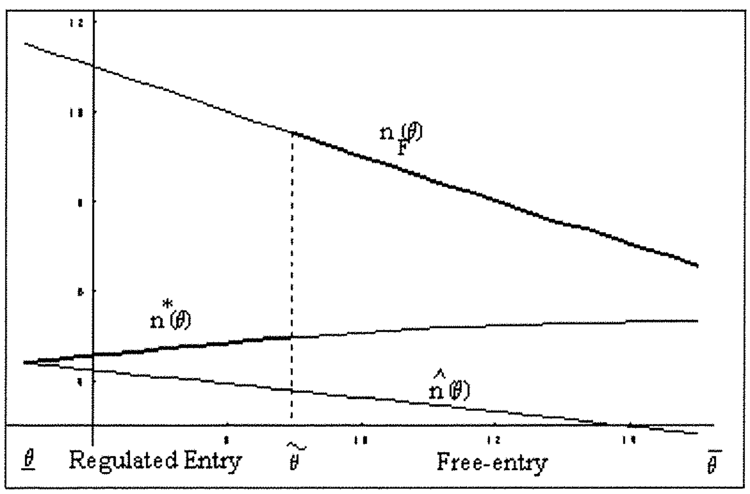

Figure 4.6: Optimal entry scheme for $a = 30$, $b = 2, F = 2, \alpha = 0.4$, $\underline{\theta} = 5$, $\overline{\theta} = 15$.

When $\alpha = 1$ regulated entry $n^*(\theta)$ is equal to the first-best level of entry. There are no distortions resulting from regulatory capture. When $\alpha < 1$, however, and except for the case where the firms have the lowest possible cost $\underline{\theta}$, regulated entry is greater than the first-best level, $\widehat{n}(\theta)$. The government faces a trade-off between restricting entry and lowering the duplication of fixed costs and reducing the rents obtained by the regulated industry.

In determining the threshold cost for regulation, $\widetilde{\theta}$, the government faces a trade-off between the benefits of free-entry and the benefits of regulated entry. Under free-entry the industry obtains no informational rents. However, there is excess entry owing to the duplication of fixed costs. Under regulated entry with capture excess entry is reduced but the regulator and industry obtains informational rents. The optimal level of $\widetilde{\theta}$ will trade off these effects.

There will always be some interval for which it is optimal to regulate entry. Consider the case where $\theta = \underline{\theta}$. There are no distortions arising from regulated entry whereas free-entry leads to a duplication of fixed costs. It is optimal to regulate entry in this case and therefore the threshold cost for regulation $\widetilde{\theta}$ must be strictly greater than $\underline{\theta}$.

For $\alpha = 1$ it is optimal to set $\widetilde{\theta} = \overline{\theta}$. The regulator will choose to regulate entry for all θ. This holds because there are no costs associated with regulatory capture in this case and regulation avoids any duplication of fixed costs. On the other hand there is excess entry in the free-entry equilibrium.

For $\alpha < 1$ the threshold cost for regulation $\widetilde{\theta}$ is determined by the distribution of marginal costs and the degree to which the government is concerned with profits. A solution for $\widetilde{\theta}$ apparently cannot be found analytically so I determine the optimal level of $\widetilde{\theta}$ for different parameter values using a simulation.[8] I assume θ is uniformly distributed on $[\underline{\theta},\overline{\theta}]$, such that the hazard rate is $H(\theta) = \theta - \underline{\theta}$, and assume the following fixed parameter values: $a = 30$, $b = 2$, $\underline{\theta} = 5$, and $\overline{\theta} = 15$. The remaining parameters values are allowed to vary. The results are shown in Table 4.1.

Clearly for low values of α, when the government is primarily concerned with consumer surplus, it is optimal to regulate entry for low realisations of θ and to adopt free-entry for high realisations of θ. ($\widetilde{\theta} < \overline{\theta} = 15$.) Free-entry is associated with higher consumer surplus and there are no informational rents. However, for high α, when

[8] The first-order condition was solved numerically for a range of parameter values. The second-order conditions were satisfied in each case.

α / F	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	7.62	7.88	8.19	8.58	9.07	9.72	10.62	11.94	14.08	15	15
2	7.56	7.81	8.11	8.49	8.97	9.61	10.49	11.78	13.86	15	15
3	7.51	7.76	8.05	8.42	8.90	9.52	10.38	11.65	13.69	15	15
4	7.47	7.71	8.00	8.37	8.83	9.45	10.29	11.54	13.55	15	15
5	7.43	7.67	7.96	8.32	8.78	9.38	10.22	11.45	13.43	15	15

Table 4.1: Optimal $\widetilde{\theta}$ for varying values of α and F

the government is strongly concerned with profits, it will be optimal to regulate entry for all θ. ($\widetilde{\theta} = \overline{\theta} = 15$.) Regulated entry lessens the duplication of fixed costs and the losses associated with regulatory capture are relatively small.

The threshold between regulated-entry and free-entry is decreasing in the fixed cost, F. As fixed costs grow there is an increase in the informational rents paid to the regulator and the industry. It therefore becomes optimal to adopt free-entry for a wider range of costs.

4.3.2 Unobservable fixed costs

Now consider the case of unobservable fixed costs. Is it ever optimal to allow free-entry into the industry? Incentive compatibility requires that free-entry only occur for high realisations of θ. However, as fixed costs grow the inefficiencies associated with free-entry rise. It may be preferable to regulate entry for all θ even with regulatory capture.

I shall now give a brief outline of the solution for unobservable fixed costs. The solution follows the same steps as in the previous sections. I assume that there is a constant unit cost, c, and a fixed set-up cost θ. The regulator has a prior probability distribution on the cost parameter θ which is summarised by the density function $g(\theta)$ with support $[\underline{\theta},\overline{\theta}]$. The hazard rate $H(\theta)$ is monotonically increasing in θ.

Given unobservable fixed costs the regulator's objective function is

$$E_\theta W = \frac{1}{2b}\int_{\widetilde{\theta}}^{\overline{\theta}}(a-c-\sqrt{b\theta})^2 dG(\theta) + \int_{\underline{\theta}}^{\widetilde{\theta}}\left\{\frac{n(\theta)(n(\theta)+2)(a-c)^2}{2(n(\theta)+1)^2 b} - n(\theta)\theta\right\} dG(\theta)$$
$$-(1-\alpha)\int_{\underline{\theta}}^{\widetilde{\theta}} n(\theta)\, H(\theta) dG(\theta). \tag{4.25}$$

The optimal level of regulated entry is found by maximising this expression pointwise with respect to $n(\theta)$.[9] The optimal threshold cost $\widetilde{\theta}$ is then found by maximising the regulator's objective function (equation (4.25)) with respect to $\widetilde{\theta}$.

The welfare-maximising scheme for entry with capture is given by

$$n^* = \begin{cases} n^*(\theta) & \text{for } \theta \leq \widetilde{\theta} \\ n_F(\theta) & \text{for } \theta > \widetilde{\theta} \end{cases},$$

where $n^*(\theta)$ satisfies

$$(n^*(\theta)+1)^3 = \frac{(a-c)^2}{b(\theta + (1-\alpha)H(\theta))} \tag{4.26}$$

and

$$n_F(\theta) = \frac{(a-c)}{\sqrt{b\theta}} - 1.$$

For fixed set-up costs less than or equal to $\widetilde{\theta}$ the regulator chooses the level of entry $n^*(\theta)$. For fixed costs higher than the threshold $\widetilde{\theta}$ the regulator allows free-entry.

The welfare-maximising threshold cost between regulated entry and free-entry is given by

$$\min[\widetilde{\theta}^*, \overline{\theta}],$$

where $\widetilde{\theta}^*$ satisfies the first-order condition

$$-\frac{1}{2b}(a-c-\sqrt{b\widetilde{\theta}^*})^2 + \frac{n^*(\widetilde{\theta}^*)(n^*(\widetilde{\theta}^*)+2)(a-c)^2}{2(n^*(\widetilde{\theta}^*)+1)^2 b}$$
$$-n^*(\widetilde{\theta}^*)(\widetilde{\theta}^* + (1-\alpha)H(\widetilde{\theta}^*)) = 0 \tag{4.27}$$

[9] For the choice of $n(\theta)$ to be globally optimal $S(\theta)$ must be a convex function of θ. This in turn requires that $n(\theta)$ is decreasing in θ. The assumption of a monotone hazard rate is sufficient to meet this condition.

Substituting the solution for $n^*(\theta)$ from equation (4.26) into equation (4.27) above and re-arranging I derive the following condition.

$$2(a-c)\sqrt{b\widetilde{\theta}^*} - b\widetilde{\theta}^* + 2bz(\widetilde{\theta}^*) - 3((a-c)bz(\widetilde{\theta}^*))^{\frac{2}{3}} = 0, \tag{4.28}$$

where $z(\widetilde{\theta}^*) = \widetilde{\theta}^* + (1-\alpha)H(\widetilde{\theta}^*)$. The marginal benefit of increasing the threshold $\widetilde{\theta}$ is the welfare from regulated entry with capture minus the welfare from free-entry given the fixed cost $\widetilde{\theta}$.

Results

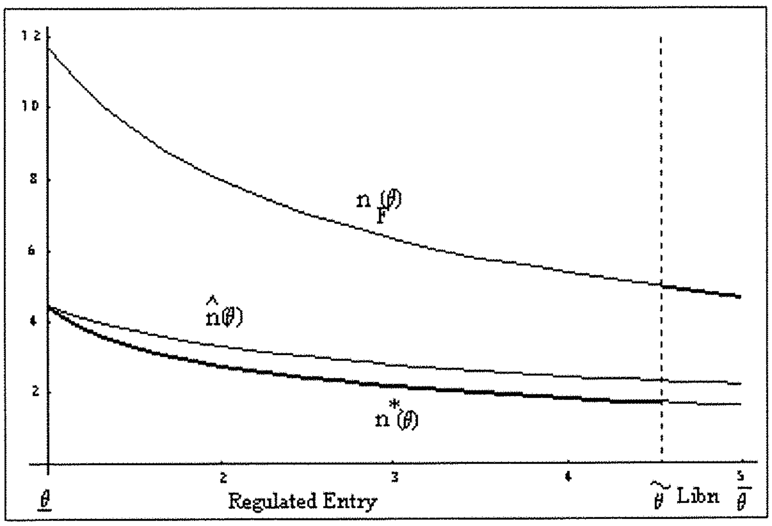

Figure 4.7: Optimal entry scheme for $a = 20$, $b = 2$, $c = 2$, $\alpha = 0$, $\underline{\theta}= 1$, $\overline{\theta} = 5$.

Under regulatory capture the government induces the regulator to choose the entry scheme n^*. The solution for entry is shown for two cases, $\alpha = 0$ and $\alpha = 0.5$, in Figures 4.7 and 4.8 respectively.

Firstly consider the case when $\alpha = 0$. For $\theta \leq \widetilde{\theta}$ the regulator sets the level of entry $n^*(\theta)$. For $\theta > \widetilde{\theta}$ it allows free-entry. It is therefore optimal to adopt free-entry under some cost conditions. Now consider the case when $\alpha = 0.5$. The regulator sets the level of entry for all realisations of θ. The welfare losses due to a duplication of fixed costs always outweigh the inefficiencies owing to regulatory capture.

When $\alpha = 1$ regulated entry $n^*(\theta)$ is equal to the first-best level of entry, $\widehat{n}(\theta)$, and less than the free-entry equilibrium number of firms, $n_F(\theta)$. There are no distortions

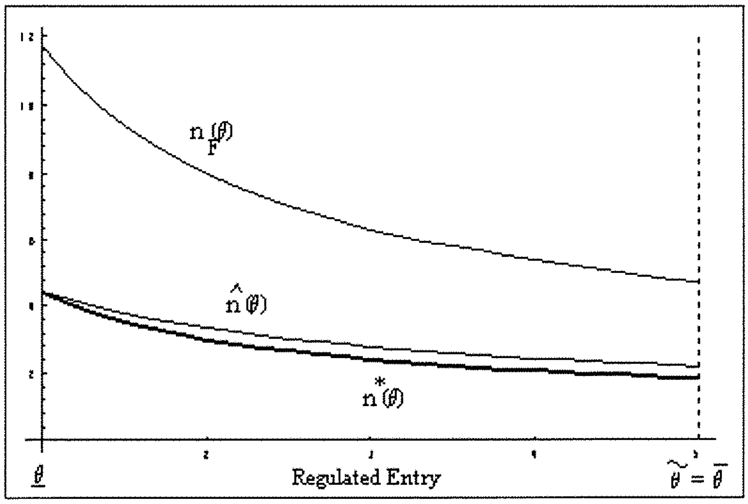

Figure 4.8: Optimal entry scheme for $a = 20$, $b = 2$, $c = 2$, $\alpha = 0.5$, $\underline{\theta}= 1$, $\overline{\theta} = 5$.

resulting from regulatory capture. When $\alpha < 1$, however, and except for the case where the firms have the lowest possible cost $\underline{\theta}$, regulated entry is less than the first-best level, $\widehat{n}(\theta)$. The government faces a trade-off between increasing entry and raising consumer surplus and lowering entry and reducing the regulated industry's rents. The level of regulated entry is decreasing is the fixed cost, F. For any level of θ the level of regulated entry $n^*(\theta)$ is less than the free-entry equilibrium number of firms, $n_F(\theta)$.

When determining the threshold cost for regulation, $\widetilde{\theta}$, the government faces a trade-off between the benefits of free-entry and the benefits of regulated entry. Under free-entry the industry obtains no informational rents. However, there is excess entry owing to the duplication of fixed costs. Under regulated entry with capture there is insufficient entry and the industry obtains informational rents. The optimal level of $\widetilde{\theta}$ will trade off these effects.

There will always be some interval of costs over which it is optimal to regulate entry. Consider the case where $\theta =\underline{\theta}$. There are no distortions arising from regulated entry whereas free-entry leads to a duplication of fixed costs. It is optimal to regulate entry in this case and hence the threshold cost for regulation $\widetilde{\theta}$ must be strictly greater

α / c	0	0.1	0.2	0.3	0.4	0.5	1
1	8.69	10.62	13.33	15	15	15	15
2	8.25	10.04	12.57	15	15	15	15
3	7.82	9.48	11.83	15	15	15	15
4	7.40	8.94	11.12	14.28	15	15	15
5	6.99	8.42	10.44	13.35	15	15	15

Table 4.2: Optimal $\widetilde{\theta}$ for varying values of α and c

than $\underline{\theta}$.

For $\alpha = 1$ it is optimal to set $\widetilde{\theta} = \overline{\theta}$. The regulator will choose to regulate entry for all θ. This holds because there are no costs associated with regulatory capture in this case and regulation avoids any duplication of fixed costs. On the other hand there is excess entry in the free-entry equilibrium.

For $\alpha < 1$ the threshold cost for regulation $\widetilde{\theta}$ will be determined by the distribution of fixed costs and the degree to which the government is concerned with profits. A solution for $\widetilde{\theta}$ apparently cannot be found analytically so the optimal level of $\widetilde{\theta}$ is found for different parameter values by solving equation (4.28) numerically.[10] I assume θ is uniformly distributed on $[\underline{\theta},\overline{\theta}]$, such that the hazard rate is $H(\theta) = \theta - \underline{\theta}$, and assume the following fixed parameter values: $a = 30$, $b = 2$, $\underline{\theta}= 5$, and $\overline{\theta} = 15$. The remaining parameters values, α and c are allowed to vary. The results are shown in Table 4.2.

Clearly for very low values of α, when the government has a strong concern for consumer surplus, it is optimal to regulate entry for low realisations of θ and to adopt free-entry for high realisations. ($\widetilde{\theta} < \overline{\theta} = 15$.) Free-entry is associated with higher consumer surplus and there are no informational rents. However, for higher values α, when the government has a stronger concern for profits, it will be optimal to regulate entry for all θ. ($\widetilde{\theta} = \overline{\theta} = 15$.) Regulated entry lessens the duplication of fixed costs and the losses associated with regulatory capture are relatively small.

[10]This was carried out using Mathematica. The second-order conditions held in each case.

For any given θ, as α increases, welfare under regulated entry rises relative to welfare under free-entry. It is optimal to regulate entry for a wider interval of costs.

The threshold cost between regulated entry and free-entry is decreasing in the marginal cost, c. For any given θ, an increase in marginal costs lowers welfare under regulated entry with capture relative to welfare under free-entry. It is therefore optimal to adopt free-entry for a wider range of costs.

4.4 Final Remarks

Liberalisation or the opening up of industries to competition has become an increasingly important part of regulatory policy towards industries. This began with the liberalisation of the airline, trucking, and telecommunications industries in the US during the 1970s and spread to many other countries during the 1980s. The UK has seen substantial liberalisation of the telecommunications industry with the introduction of competition to the production of apparatus, network operation and the supply of services. Some degree of liberalisation has also taken place in the gas and electricity industries, and further liberalisation measures are in progress. I have been concerned with finding the conditions under which it is optimal to liberalise an industry rather than to maintain a regulated monopoly. I find that when marginal costs are unobservable and there are very strong natural monopoly conditions (there is a high level of fixed costs) or the regulator gives a high weight to profits it is never optimal to liberalise. The costs of liberalisation in terms of duplicating fixed costs outweigh any inefficiencies due to regulation. More generally it is optimal to maintain a regulated monopoly for low realisations of costs and to liberalise an industry for high realisations of costs. If the regulator places greater weight on distributional concerns liberalisation becomes optimal for a wider interval of costs as informational rents become more costly, while the costs of liberalisation remain constant. By contrast with unobservable and uniformly distributed fixed costs it is never optimal to liberalise an industry.

There was substantial concern in the US before liberalisation that many regulatory agencies were "captured" by the industries they were designed to regulate and acted to limit entry and protect incumbent firms' profitability. I have examined the optimal choice between regulated entry with capture and free-entry. In the case of unobservable marginal costs regulatory capture increases the level of entry into an industry, while for unobservable fixed costs it reduces the level of entry. I find that when the government has a strong concern for profits it is always optimal to allow regulated entry. More generally it is optimal to regulate entry for low realisations of costs and to adopt free-entry for high realisations. If the regulator places greater weight on profits it becomes optimal to adopt regulated entry for a wider range of costs as informational rents become less costly.

Possible extensions to these models include introducing different technologies for potential entrants, considering weaker forms of regulatory capture, and possible alternatives to free-entry such as a duopoly.

Appendix A Optimal Threshold Cost

The first-order condition for an interior solution for the optimal threshold cost is

$$\frac{dE_\theta W(\theta)}{d\widetilde{\theta}} = \frac{1}{2b}(a-\widetilde{\theta}-(1-\alpha)H(\widetilde{\theta}))^2 - F - \frac{1}{2b}(a-\widetilde{\theta}-\sqrt{bF})^2 = 0. \tag{A4.1}$$

The second derivative of expected welfare with respect to the threshold cost is

$$\begin{aligned}\frac{d^2E_\theta W(\theta)}{d\widetilde{\theta}^2} &= \frac{1}{b}(a-\widetilde{\theta}-\sqrt{bF}) - \frac{1}{b}(a-\widetilde{\theta}-(1-\alpha)H(\widetilde{\theta})) - \\ &\frac{1}{b}(1-\alpha)H'(\widetilde{\theta})(a-\widetilde{\theta}-(1-\alpha)H(\widetilde{\theta})).\end{aligned} \tag{A4.2}$$

Suppose there is an interior solution, $\widetilde{\theta}^* < \overline{\theta}$, which satisfies equation (A4.1). $\widetilde{\theta}^* < \theta^E$, where θ^E satisfies$(1-\alpha)H(\theta^E) = \sqrt{bF}$. The first-order condition is positive over the interval $[\underline{\theta}, \widetilde{\theta}^*)$ and negative over the interval $(\widetilde{\theta}^*, \overline{\theta}]$. The second derivative is strictly negative over the interval $[\underline{\theta},\theta^E]$. The interior solution is therefore a maximum and unique. Otherwise the optimal threshold cost must be $\overline{\theta}$.

Appendix B Comparative Statics

Differentiating the first-order condition for the optimal liberalisation threshold with respect to α gives the condition:

$$\left.\frac{d^2E_\theta W}{d\widetilde{\theta}d\alpha}\right|_{\widetilde{\theta}=\widetilde{\theta}^*} = \frac{1}{b}H(\widetilde{\theta}^*)(a-\widetilde{\theta}^*-(1-\alpha)H(\widetilde{\theta}^*)) > 0.$$

Combined with equation (A4.2) this implies that $\dfrac{d\widetilde{\theta}^*}{d\alpha} > 0$ for $\widetilde{\theta}^* < \overline{\theta}$.

Differentiating the first-order condition for the optimal liberalisation threshold with respect to F gives the condition:

$$\left.\frac{d^2E_\theta W}{d\widetilde{\theta}dF}\right|_{\widetilde{\theta}=\widetilde{\theta}^*} = \frac{1}{2\sqrt{bF}}(a-\widetilde{\theta}^*-\sqrt{bF})-1 > 0.$$

Combined with equation (A4.2) this implies that $\dfrac{d\widetilde{\theta}^*}{dF} > 0$ for $\widetilde{\theta}^* < \overline{\theta}$.

Differentiating the first-order condition for the optimal liberalisation threshold with respect to b and gives the condition:

$$\begin{aligned}\left.\frac{d^2E_\theta W}{d\widetilde{\theta}db}\right|_{\widetilde{\theta}=\widetilde{\theta}^*} &= \frac{1}{2b^2}[(a-\widetilde{\theta}^*-\sqrt{bF})^2+\sqrt{bF}(a-\widetilde{\theta}^*-\sqrt{bF}) \\ &\quad -(a-\widetilde{\theta}^*-(1-\alpha)H(\widetilde{\theta}^*))^2].\end{aligned}$$

Substituting in equation (A4.1) and rearranging gives:

$$\left.\frac{d^2E_\theta W}{d\widetilde{\theta}db}\right|_{\widetilde{\theta}=\widetilde{\theta}^*} = \frac{1}{2b^2}[\sqrt{bF}(a-\widetilde{\theta}^*-\sqrt{bF})-2bF] > 0.$$

Combined with equation (A4.2) this implies that $\dfrac{d\widetilde{\theta}^*}{db} > 0$ for $\widetilde{\theta}^* < \overline{\theta}$.

Chapter 5

Conclusions

The introduction emphasised a number of potentially conflicting objectives for regulatory policy. Regulation should ensure that prices closely reflect avoidable costs. In an uncertain environment regulatory policy should be flexible, but also provide sufficient stability for investors to be confident of an adequate return on their investments. There should be strong incentives for investment in cost-reducing effort and the development of new products. Regulatory policy should ensure that firms meet the demand for their services and maintain a reasonable quality of supply. Ideally regulatory regimes would meet all of these concerns, but in practice there are a number of constraints on the design of regulatory policies which force regulators to compromise between these objectives and which give rise to inefficiencies. Regulatory agencies are often less informed than the firms they regulate. They may be unable to offer them subsidies. Most importantly, in the context of this thesis, regulators may be unable to commit to their announced policies.

A lack of regulatory commitment allows opportunistic behaviour by the regulator and may result in significant inefficiencies. For example, firms may underinvest in relationship specific assets if they fear that the regulator will expropriate some of the returns on their investment. Firms may be reluctant to reveal information early in a regulatory relationship if they believe the regulator will use this information to tighten incentive schemes. Credible commitments to policy are therefore essential if regulators are to overcome problems of underinvestment. Such commitments, however, often mean sacrificing the flexibility to adapt policies to a changing environment.

Chapter 2 examined the relative benefits of commitment and discretion and highlighted the factors that are important in determining the optimal level of commitment. In essence there is a trade-off between allocative efficiency, productive efficiency and distributional concerns. High levels of commitment provide strong incentives for investment, but reduce allocative efficiency and allow the firm to earn large informational rents. High levels of discretion, on the other hand, offer only weak incentives for investment, but allow the regulator the opportunity to adjust prices once any cost uncertainty has been resolved. A number of factors are important in determining the outcome of this relationship. The optimal level of commitment is decreasing in the level of uncertainty. As the level of uncertainty grows the convexity of consumer surplus means that allocative efficiency is improved if the regulator has more flexibility to adjust prices in line with realised costs. Increases in elasticity reduce the optimal level of commitment. As demand becomes more elastic the convexity of consumer surplus increases and there are greater gains from discretion. Finally, the optimal level of commitment is increasing in the regulator's weight on profits, as the regulator becomes less concerned about conferring rents on the firm.

Countries with long histories of low investment and weak legal institutions are ideal candidates for regulatory regimes with high levels of commitment. Low credibility and high costs of investment mean that commitment is necessary to give firms adequate incentives to invest. However, if a country has credible legal institutions and has sustained high levels of investment in the past, flexible regimes may be more appropriate.

A number of interesting extensions may be pursued. The commitment model focuses on the case of uncertain marginal costs. I believe that similar results would be obtained if demand uncertainty were considered. Although, I have only considered a single dimension of uncertainty, it would be interesting to examine how two types of uncertainty would affect my results. Another interesting extension would be to consider the regulation of a multi-product monopolist. This would allow for the possibility of several policy instruments and different levels of commitment for each instrument.

Partial privatisation may be an important means of securing commitment to regulatory policies. Chapter 3 considered the partial privatisation of a monopolistic firm under imperfect information and the determinants of the optimal level of privatisation. There are clearly significant benefits from the government retaining equity in the firms it privatises. The retention of equity brings its interests closer in line with those of private shareholders and thereby reduces its incentives to act opportunistically and expropriate the returns from cost-reducing effort. Governments may obtain a higher level of consumer surplus and revenues than under complete privatisation and many investment projects may take place which would otherwise have been neglected. Partial privatisation is, in effect, a form of commitment to higher regulated prices and can thereby sustain higher levels of welfare.

The level of privatisation is important in determining government incentives for price regulation and the amount of sunk effort undertaken by the manager of a partially privatised firm. Neither full public ownership nor complete privatisation is optimal as the government will expropriate all the returns from the manager's cost-reducing effort. Anticipating this behaviour the manager will choose not to invest. The optimal level of privatisation trades off the government's objectives of allocative efficiency, productive efficiency, and raising revenues. As more shares are sold to the owner-manager of the privatised firm she receives a greater proportion of the firm's profits and has stronger incentives to improve productive efficiency. This raises the ex-ante value of the firm and the government's privatisation revenues. On the other hand, the government becomes more concerned with improving allocative efficiency, which increases the risk of expropriation and reduces the firm's value. The optimal level of privatisation must balance these effects.

A number of factors are significant in determining the outcome of this trade-off. An increase in the distortionary effects of taxation raises the optimal level of privatisation. A higher shadow price of public funds implies that the regulator is relatively more concerned with improving productive efficiency and less concerned with raising consumer surplus. The government therefore expropriates less of the returns from cost-reducing effort in the final stage of the game and chooses to sell more of the firm's equity. An increase in marginal benefit of effort (the difference in profits between states) raises the optimal level of privatisation. The government chooses to sell more of the firm's equity to give the manager more powerful incentives to improve productive efficiency. An increase in the cost of effort reduces the optimal level of privatisation. As the cost of effort increases the marginal benefit of selling equity declines. The government therefore chooses to retain a greater proportion of the firm's shares.

The privatisation-regulation model focuses on the partial privatisation of a monopolistic firm, whose prices are regulated by the government, to an owner-manager. The manager's only incentive scheme is a share of the firm's profits. A number of interesting extensions could be pursued. A three tier principal-agent model would allow for richer relationships between the government, private shareholders and the manager. Suppose the government sells a proportion of the firm's shares to a representative private shareholder, who then appoints a manager, sets an appropriate incentive scheme, and monitors the manager's behaviour. Higher levels of privatisation may lead to more monitoring and a greater level of effort by the manager, raising the share price. However, as the government sells more of the firm's shares it may become more concerned with setting a low regulated price, lowering the share price. The optimal level of privatisation would trade off these effects. It would be equally interesting to develop a dynamic model of the optimal speed of privatisation. Once again there is a commitment problem as rapid privatisation gives the government an incentive to act opportunistically and set a low regulated price, such that the firm's shares have little value. It may be optimal for the government to privatise more slowly, increasing the credibility of its announced policies and its privatisation revenues.

Even if privatisation policies are well designed and regulatory policies are framed in a manner which overcomes any commitment problems important inefficiencies may remain. For example if a firm has private cost information and the regulator places greater weight on consumer surplus than on profits, the optimal regulatory policy sacrifices some allocative efficiency in order to reduce informational rents. Baron and Myerson (1982) show that it is optimal to set the regulated price equal to the sum of the firm's marginal production and information costs. Under such circumstances it may be preferable to liberalise an industry rather than to continue inefficient regulation.

Since the 1970s liberalisation has become a key part of government industrial policy in many countries. The UK has recently seen the liberalisation of the telecommunications industry and a significant degree of liberalisation has also taken place in the gas and electricity markets. Chapter 4 was concerned with finding the conditions under which it is optimal to liberalise an industry rather than pursue regulation of a monopolistic firm. I find that when marginal costs are unobservable and there are very strong natural monopoly conditions or the regulator gives a high weight to profits it is never optimal to liberalise. The costs of liberalisation in terms of duplicating fixed costs outweigh any inefficiencies due to regulation. More generally it is optimal to regulate a monopolistic firm for low realisations of costs and to liberalise for high realisations of costs. By contrast if fixed costs are unobservable and uniformly distributed it is never optimal to liberalise.

An alternative application of the model in Chapter 4 was used to consider the effects of regulatory capture on entry decisions. When marginal (fixed) costs are unknown the level of entry is distorted upwards (downwards) relative to the efficient level. If the government has a strong concern for profits it is always optimal to allow regulated entry. More generally it is optimal to regulate entry for low realisations of costs and to allow free-entry for high realisations.

The are a number of ways in which this research could be extended. The regulation-liberalisation model focuses on the case of potential entrants which have access to the same technology as the incumbent. I also assume that there is no first-mover advantage. It would be interesting to examine how entrants with different cost levels would affect my results. If the incumbent is modelled as a Stackelberg leader it may be optimal to retain regulation for a wider range of costs as the benefits of liberalisation are reduced. Although I have only considered one dimensional uncertainty it would be interesting to determine when it is optimal to liberalise an industry when both marginal and fixed costs are unknown.

The successful design of regulatory institutions requires that governments find a suitable balance between regulatory commitment and discretion. This enables regulators to pursue policies that both foster high levels of investment and ensure that the benefits of lower costs are passed onto consumers. Partial privatisation is one possible mechanism for achieving such commitment. If regulatory inefficiencies prove too great then ultimately liberalisation may be the answer. I have suggested a number of avenues for future research in this area.

REFERENCES

M. Armstrong. Delegating Decision-Making to an Agent with Unknown Preferences. Mimeo: University of Southampton, 1995.

M. Armstrong. Optimal Regulation with Unknown Demand and Cost Functions. *Journal of Economic Theory*, 84:196–215, 1999.

M. Armstrong, S. Cowan, and J. Vickers. *Regulatory Reform: Economic Analysis and the British Experience.* The MIT Press, 1996.

M. Armstrong, C. Doyle, and J. Vickers. The Access Pricing problem: A Synthesis. *Journal Of Industrial Economics*, 44:131–50, 1996.

M. Armstrong, R. Rees, and J. Vickers. Optimal Regulatory Lag under Price-Cap Regulation. *Revista Espanola de Economia*, pages 93–116, 1995.

M. Armstrong and J. Vickers. Regulatory Reform in Telecommunications in Central and Eastern Europe. *Economics of Transition*, 4:295–318, April 1996.

H. Averch and L. Johnson. Behaviour of the Firm under Regulatory Constraint. *American Economic Review*, 52:1052–1069, 1962.

D. Backus and J. Driffill. Inflation and Reputation. *American Economic Review*, 75:530–538, 1985a.

D. Backus and J. Driffill. Rational Expectations and Policy Credibility Following a Change in Regime. *Review of Economic Studies*, 52:211–221, 1985b.

C. Ballard, J. Shoven, and J. Whalley. General equilibrium computations of the marginal welfare costs of taxes in the United States. *American Economic Review*, 75:128–138, 1985.

D. P. Baron and D. Besanko. Regulation, Asymmetric information, and Auditing. *Rand Journal of Economics*, 15:447–470, 1984a.

D. P. Baron and D. Besanko. Regulation and Information in a Continuing Relationship. *Information Economics and Policy*, 1:267–302, 1984b.

D. P. Baron and D. Besanko. Commitment and Fairness in a Dynamic Regulatory Relationship. *Review of Economic Studies*, 54:413–436, 1987.

D. P. Baron and R. B. Myerson. Regulating a Monopolist with Unknown Costs. *Econometrica*, 50:911–930, 1982.

R. Barro and D. Gordon. A Positive Theory of Monetary Policy in a Natural-Rate Model. *Journal of Political Economy*, 91:589–610, 1983a.

R. Barro and D. Gordon. Rules, Discretion, and Reputation in a Model of Monetary Policy. *Journal of Monetary Economics*, 12:101–121, 1983b.

G. Biglaiser and C.-t. A. Ma. Investment Incentives of a Regulated Dominant Firm. *Journal of Regulatory Economics*, 1999 forthcoming.

C. Bliss and R. Di Tella. Does Competition Kill Corruption? *Journal of Political Economy*, 105:1001–1023, 1997.

D. Bös. *Privatization. A Theoretical Treatment.* Clarendon Press, Oxford, 1991.

D. Bös and P. Harms. Mass Privatization, Management control and Efficiency. *Journal of Public Economics*, 64:343–357, 1997.

D. Bös and W. Peters. Privatization and Economic Efficiency. Discussion paper a-79, Institute of Economics, Bonn University, 1986.

W. A. Brock and S. P. Magee. The economics of politics. Mimeo: University of Chicago, 1974.

W. A. Brock and S. P. Magee. The Economics of Pork-Barrel Politics. Report no. 7511, Center for Mathematical Studies in Business and Economics, University of Chicago, 1975.

B. Caillaud. Regulation, Competition, and Asymmetric Information. *Journal of Economic Theory*, 52:87–110, 1990.

G. Clemenz. Optimal Price-Cap Regulation. *Journal of Industrial Economics*, 39:391–409, 1991.

R. Coase. Price and output policy of state enterprise: A comment. *Economic Journal*, 55:112–113, 1945.

R. Coase. The marginal cost controversy. *Economica*, 13:113–28, 1946.

F. Coricelli and G. Milesi-Ferretti. On the Credibility of "big-bang" Programs. *European Economic Review*, 37:387–395, 1993.

J. Dana. The Organization and Scope of Agents. *Journal of Economic Theory*, 59:288–310, 1993.

J. Demski and D. E. M. Sappington. Optimal incentive contracts with multiple agents. *Journal of Economic Theory*, 33:152–71, 1984.

M. Dewatripont and G. Roland. The Design of Reform Strategies under Uncertainty. Discussion paper no. 860, Center for Economic Policy Research, 1993.

J. Dupuit. De la Mesure de L'utilité Des Travaux Publics. *Annales des Ponts et Chausées*, 8, 1844. Translation in AEA Readings in Welfare Economics, ed. K Arrow and T. Scitovsky.

X. Freixas, R. Guesnerie, and J. Tirole. Planning under Incomplete Information and the Ratchet Effect. *Review of Economic Studies*, 52:173–192, 1985.

R. J. Gilbert and D. M. Newbery. The dynamic efficiency of regulatory constitutions. *Rand Journal of Economics*, 25:538–554, 1994.

S. J. Grossman and O. D. Hart. Takeover Bids, the Free Rider Problem and the Theory of the Corporation. *Bell Journal Of Economics*, 11:349–364, 1980.

S. J. Grossman and O. D. Hart. The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration. *Journal of Political Economy*, 94:691–719, 1986.

O. D. Hart. *Firms, Contracts, and Financial Structure.* Clarendon Press, Oxford, 1995.

J. Haskel and S. Szymanski. A bargaining theory of privatization. *Annals of Public and Cooperative Economics*, 63:207–227, 1992.

J. Haskel and S. Szymanski. Privatization, Liberalisation, Wages and Employment: Theory and Evidence for the UK. *Economica*, 60:161–181, 1993.

D. Heald. *Privatisation and Public Money*, chapter 2, pages 21–43. Royal Institute of Public Administration, 1984.

B. Holmström. Managerial Incentive Problems: A Dynamic Perspective. *Review of Economic Studies*, 66:169–182, 1999.

G. Houston. The cost of regulatory rule changes in the UK. NERA, 1998.

N. J. Ireland. Fairness in Regulation and Privatisation. Mimeo: University of Warwick, 1995.

L. P. Jones. Appropriate Regulatory Technology. The Interplay of Economic and Institutional Conditions. *Proceedings of the World Bank Annual Conference on Development Economics*, pages 181–204, 1993.

P. Klemperer, editor. *The Economic Theory of Auctions.* Edward Elgar, Cheltenham, UK, 1999a.

P. Klemperer. Auction Theory: A Guide to the Literature. Mimeo: Nuffield College, Oxford University, 1999b.

F. Kyland and E. Prescott. Rules Rather Than Discretion: The Inconsistency of Optimal Plans. *Journal of Political Economy*, 85:473–491, 1977.

J.-J. Laffont and D. Martimort. Transaction Costs, Institutional Design and the Separation of Powers. *European Economic Review*, 42:673–684, 1998.

J.-J. Laffont and D. Martimort. Separation of Regulators Against Collusive Behavior. *Rand Journal of Economics*, 30:232–262, 1999.

J.-J. Laffont and J.-C. Rochet. Regulation of a Risk Averse Firm. *Games and Economic Behaviour*, 25:149–173, 1998.

J.-J. Laffont and J. Tirole. Using cost information to regulate firms. *Journal of Political Economy*, 94:614–641, 1986.

J.-J. Laffont and J. Tirole. Should Governments Commit? *European Economic Review*, 36:345–354, 1992.

J.-J. Laffont and J. Tirole. *A Theory of Incentives in Procurement and Regulation.* Cambridge: MIT Press, 1993.

J.-J. Laffont and J, Tirole. Access pricing and competition. *European Economic Review*, 38:1673–1710, 1994.

B. Levy and P. T. Spiller. The Institutional Foundations of Regulatory Commitment: A Comparative Analysis of Telecommunications Regulation. *Journal of Law, Economics and Organisation*, 10:201–246, 1994.

B. Levy and P. T. Spiller, editors. *Regulations, Institutions and Commitment.* Cambridge University Press, 1996.

T. R. Lewis and D. E. M. Sappington. Regulating a Monopolist with Unknown Demand. *American Economic Review*, 78:986–998, 1988a.

T. R. Lewis and D. E. M. Sappington. Regulating a Monopolist with Unknown Demand and Cost Functions. *Rand Journal of Economics*, 19:438–457, 1988b.

T. R. Lewis and D. E. M. Sappington. Optimal Capital Structure in Agency Relationships. *Rand Journal of Economics*, 26:343–361, 1995.

M. Loeb and W. Magat. A decentralized method of utility regulation. *Journal of Law and Economics*, 22:399–404, 1979.

S. P. Magee, W. A. Brock, and L. Young. *Black Hole Tariffs and Endogenous Policy Theory. Political Economy in General Equilibrium.* Cambridge University Press, Cambridge, England, 1989.

J. M. Malcomson. Contracts, Hold-Up and Labor Markets. *Journnal of Economic Literature*, XXXV:1916–1957, 1997.

N. G. Mankiw and M. D. Whinston. Free Entry and Social Inefficiency. *Rand Journal of Economics*, 17:48–58, 1986.

C. Mayer and S. Meadowcroft. Selling Public Assets: Techniques and Financial Implications. *Fiscal Studies*, 6:42–56, 1985.

C. Mayer and J. Vickers. Profit-Sharing Regulation: An Economic Appraisal. *Fiscal Studies*, 17:1–18, 1996.

R. P. McAfee and J. McMillan. Auctions and Bidding. *Journal of Economic Literature*, 25:699–738, 1987.

A. S. Mello and J. E. Parsons. Going public and the ownership structure of the firm. *Journal of Financial Economics*, 49:79–109, 1998.

P. R. Milgrom and J. Roberts. Limit Pricing and Entry under Incomplete Information: An Equlibrium Analysis. *Econometrica*, 50:443–459, 1982.

J. Mirrlees. An Exploration in the Theory of Optimum Income Taxation. *Review of Economic Studies*, 38:175–208, 1971.

D. M. Newbery. Restructuring and Privatising Electric Utilities in Eastern Europe. *Economics of Transition*, 2:291–316, 1994.

B. Nomer, R. Disney, and C. J. Ellis. Privatisation and Strategic Monitoring. Economics discussion paper no. 364, Queen Mary and Westfield College, 1997.

T. E. Olsen and G. Torsvik. Collusion and Renegotiation in Hierarchies: A Case of Beneficial Corruption. *International Economic Review*, 39:413–438, 1998.

T. E. Olsen and G. Torsvik. The Ratchet Effect in Common Agency: Implications for Regulation and Privatisation. *Journal of Law, Economics and Organisation*, 9:136–158, 1993.

S. Peltzman. Towards a More General Theory of Regulation. *Journal of Law and Economics*, 14:109–48, 1976.

R. Posner. Taxation by Regulation. *Bell Journal of Economics*, 2:22–50, 1971.

R. Posner. Theories of Economic Regulation. *Bell Journal of Economics*, 5:335–358, 1974.

D. J. Salant. Behind the Revolving Door: A New View of Public Utility Regulation. *Rand Journal of Economics*, 26:362–377, 1995

D. J. Salant and G. A. Woroch. Crossing Dupuit's Bridge Again: A Trigger Policy for Efficient Investment in Infrastructure. *Contemporary Policy Issues*, 9:101–114, 1991.

D. J. Salant and G. A. Woroch. Trigger Price Regulation. *Rand Journal of Economics*, 23:29–51, 1992.

D. E. M. Sappington. Commitment to regulatory bureaucracy. *Information Economics and Policy*, 2:243–258, 1986.

F. M. Scherer. Research and Development Resource Allocation under Rivalry. *Quarterly Journal of Economics*, 81:359–394, 1967.

K. M. Schmidt. Incomplete contracts and privatization. *European Economic Review*, 40:569–579, 1996a.

K. M. Schmidt and M. Schnitzer. Methods of Privatization: Auctions, Bargaining and Give-Aways. Discussion Paper no. 1541, Center for Economic Policy Research, 1997.

A. Shleifer. A theory of yardstick competition. *Rand Journal of Economics*, 16:319–327, 1985.

M. Spence. *Market Signalling: Informational Transfer in Hiring and Related Processes.* Harvard University Press, Cambridge, M.A., 1974.

Y. Spiegel and D. F. Spulber. The capital structure of a regulated firm. *Rand Journal of Economics*, 25:424–446, 1994.

G. J. Stigler. The Theory of Economic Regulation. *Bell Journal of Economics*, 2:3–21, 1971.

J. Vickers. Privatization and the Risk of Expropriation. *Revista di politica economica*, 81:115–146, 1991.

J. Vickers. Competition and regulation in vertically related markets. *Review of Economic Studies*, 62:1–17, 1995a.

J. Vickers and G. Yarrow. *Privatization. An Economic Analysis.* MIT Press, 1988.

W. Vickrey. Counterspeculation, Auctions, and Competitive Sealed Tenders. *Journal Of Finance*, 16:8–37, 1961.

M. Weitzman. The Ratchet Principle and Performance Incentives. *Bell Journal of Economics*, 11:302–308, 1980.

O. Williamson. *Markets and Hierarchies: Analysis and Antitrust Implications.* New York: Free Press, 1975.

O. Williamson. Credible Commitments: Using Hostages to Support Exchange. *American Economic Review*, 83:519–540, 1983.

O. Williamson. *The Economic Institutions of Capitalism.* New York: Free Press, 1985.

L. Zingales. Insider ownership and the decision to go public. *Review of Economic Studies*, 62:425–448, 1995.